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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1887 *TO NOVEMBER* 1888.

VOL. XLVIII.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

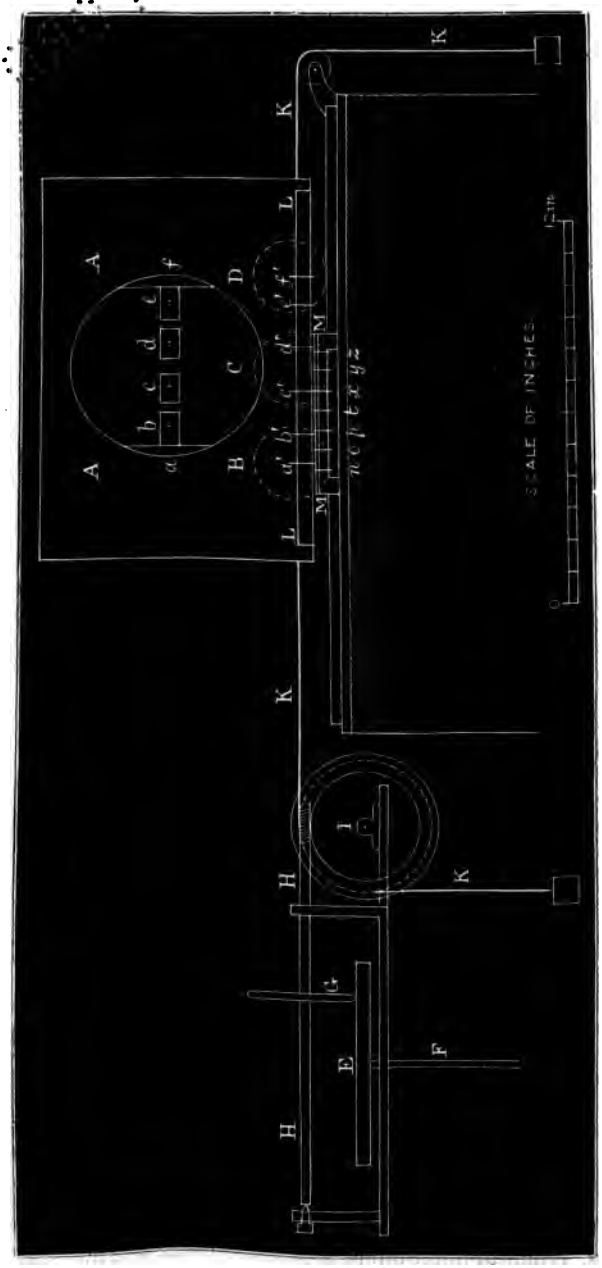
VOL. XLVIII. NOVEMBER 11, 1887 No. 1

J. W. L. GLAISHER, Sc.D., F.R.S., President, in the Chair.

Thomas Bauchope, East Brucefield, West Calder, Scotland, was balloted for and duly elected a Fellow of the Society.

Description of the Personal Equation Machine of the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

This apparatus was planned with a view of determining absolute personal equations, the variations of personal equation depending upon the direction of movement, the velocity, and the magnitude of the star observed, and personality in observations of limbs of the Sun, Moon, or planets. It was arranged that the transit-circle should be used for the determinations, and a point which I specially aimed at was that the conditions of the ordinary observations of the heavenly bodies should be reproduced as closely as possible. Generally speaking, this personal equation machine is on the lines of that devised by M. C. Wolf, and described by him in vol. viii. of the *Annales de l'Observatoire de Paris;* but, as the objects in view were somewhat different, various modifications in the general plan were introduced. Amongst these may be mentioned the much larger dimensions of the apparatus (in consequence of which it is not necessary to use a lens of short focus to form a diminished image of the artificial object), the use of the transit-circle micrometer for adjustment of the contacts to the true transit over the wires, and the use of reflected sunlight, moonlight, or diffused daylight, instead of lamplight. This being premised, I proceed to describe the construction of the apparatus, which was made by Messrs. Troughton & Simms with their usual skill.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An object-glass of 7½ inches aperture, and of about 51 feet focal length, is attached in front of the object-glass of the transit-circle, the telescope tube of the latter being horizontal and pointing north. This long-focus object-glass forms, in fact, a reversed telescope or collimator, in the focus of which is the vertical plate A of the personal equation machine, apertures in which, illuminated by sunlight, moonlight, or diffused skylight reflected from a plane mirror behind, form the artificial objects to be observed. A circular aperture in the plate 6 inches in diameter represents the Sun or Moon, and as only the portions *a*, *f*, near the ends of the horizontal diameter, are required for observations of first and second limbs, the remainder of the aperture is filled by a plate carrying four small pinholes *b*, *c*, *d*, *e* (to represent stars of different magnitudes) adjustable in a horizontal slide. The vertical plate is mounted on a carriage with three grooved wheels (B, C, D) running on two horizontal rails, and carried smoothly by clockwork from east to west, or west to east, at a rate which, by means of an ingenious contrivance devised by Mr. James Simms, may be varied at will from that of a very close circumpolar star to about three times that of an equatorial star. The movement of the vertical plate is effected in the following manner:—A horizontal circular brass plate E is attached to the vertical spindle F of an equatorial driving clock (belonging to one of the photoheliographs), and is thus made to rotate uniformly at a determinate speed. This plate drives by rolling friction a brass disc G, turning about a horizontal axis H, and placed with its rim in contact with the plate. The disc G can be slipped along its spindle and clamped at any point, so that the point of contact of the disc and plate can be adjusted at will to any distance from the centre of the latter, the angular velocity of the disc varying directly as this distance, and changing sign at the centre. At the further end of the spindle is a screw which gears into a toothed wheel I, and communicates the motion to the vertical plate by means of a pulley-wheel (in the same casting with the toothed wheel), and a cord K kept in tension by weights at each end. The carriage on which the vertical plate is mounted can be attached to any convenient point of the cord.

The transits of the artificial sun, or moon and stars can thus be observed with the transit-circle under practically the same conditions as the real objects. At the same time, the true times of transit over the wires are registered automatically on a chronograph by means of the contacts between two sets of platinum studs, one set (a', b', c', d', e', f') corresponding to the artificial objects and carried with the plate, the other set (n, o, p, q, r, s, t, u, v, w, x, y, z) fixed and corresponding to the wires of the transit-circle. [In the diagram q, r, s, u, v, w are omitted to avoid confusion.] The platinum studs are carefully rounded at the parts where contact is made (so that the contact surfaces are hemispheres) and are let into the ends of small brass screws,

which are tapped through insulated narrow brass plates L, M, having thin plates of ebonite (with holes through which the studs project very slightly) on their under and upper surfaces respectively. The studs can thus be readily adjusted vertically to give good contact without interfering with the smooth motion of the vertical plate. For the adjustment of the instants of contact to the times of true transit over the wires, the right ascension micrometer of the transit-circle is used to move the wires so that they respectively bisect the artificial object when it is brought (by slowly turning the spindle of the screw which actuates the pulley wheel) into the respective positions for which contact is made by its stud with each of the studs corresponding to the wires. The readings of the R.A. micrometer are taken for the bisection of the artificial star by each wire, and the micrometer is set to the mean of the readings. A reversion-prism eyepiece is used in these adjustments to eliminate any personality in bisection of a stationary object. Thus the mean of the true times of transit over the wires is adjusted to agree precisely with the mean of the instants of contact with the corresponding studs.

In observations of limbs I propose to use an artificial star as a point of reference, measuring the distance between the artificial limb and star on the plate with a micrometer microscope, and also in the field of view of the transit-circle with the R.A. micrometer. The scale would be given by measuring the distance between two stars on the plate and in the field of the transit-circle. In this way personality in the bisection of a stationary limb would be determined, and the personality in observations of a first or second limb would be found by means of transits. It may be remarked that the reversion-prism eyepiece gives facilities for converting the preceding or following limb (*a* or *b*) into an upper or lower limb, so that personality in N.P.D. observations of limbs can be thus determined.

Plates with apertures representing the various planets may be substituted for any of the four *b*, *c*, *d*, *e*.

Royal Observatory, Greenwich:
1887, *November* 19.

Results obtained with the Personal Equation Machine at the Royal Observatory, Greenwich. By H. H. Turner, M.A., B.Sc.

A full description of the Personal Equation Machine is given by the Astronomer Royal in the preceding paper. Observations were made with this instrument in 1885 and 1886, but, owing to pressure of other work, little more was done than was necessary to test the general practicability of the measures. A series of transits of an artificial star was observed by several observers, the apparent rate of motion being a little greater than that of an equatorial star, and alternately towards

the left (*l*), and towards the right (*r*). This reversal of apparent direction of motion can be obtained either by reversing the actual motion of the plate or by using the reversion-prism eyepiece with the transit-circle; and to eliminate certain errors, both methods were employed in combination. The letters *l* (towards the left of the observer) and *r* (towards the right) are always used to designate the resulting apparent direction of motion, the actual motion of the plate being defined by the letters E (towards the east) and W (towards the west). With the ordinary eyepiece the apparent motion is towards the left when the plate moves towards the east.

The transits were registered automatically on the chronograph which is used for ordinary star observation, the electromagnet usually connected with the clock being temporarily placed in the circuit connected with the instrumental studs. The record made by the observer was made exactly in the same manner as that for the transit of a star, except that the instrument was in a horizontal position and the observer standing erect, which only occurs approximately in the case of stars near the horizon.

The following are the results obtained for absolute personal equation, the sign + signifying that the observer is late in his record. The relative personal equation in use for all objects without distinction, and referred to Mr. Downing as standard observer, is placed in brackets after each observer's name for comparison. The initials H.T., C., A.D., T., L., H., S.D. and R., are those of Mr. Turner, Mr. Criswick, Mr. Downing, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. Dolman, and Mr. Robinson respectively.

Each printed number is the mean of a transit of nine wires.

Observer, H. T. (−0ˢ·15.)

	Apparent Motion *l*.		Apparent Motion *r*.	
	E.	W.	E.	W.
	s	s	s	s
1885, Aug. 26	+0·07			+0·03
	+0·10			+0·04
	+0·31			+0·03
	+0·26			+0·11
	+0·09			+0·08
1886, May 9	+0·01	−0·02	−0·06	+0·14
	−0·02	+0·03	−0·01	+0·04
May 10	−0·04	−0·04	+0·01	−0·05
27	−0·06	−0·09	−0·09	−0·10
	+0·03	−0·16	−0·15	−0·12
Mean	+0·075	−0·056	−0·060	+0·020
Mean, excluding 1885, Aug. 26	−0·016	−0·056	−0·060	−0·018

Observer C. (+0".28.)

	Apparent Motion *l*. E.	W.	Apparent Motion *r*. E.	W.
	s	s	s	s
1885, Aug. 26	+0·45			+0·35
	0·28			0·35
	0·34			0·28
	0·34			0·42
	0·34			0·26
1886, May 18	0·27	+0·22		0·14
	0·31	+0·22		+0·19
	0·25			
	+0·28			
Mean	+0·318	+0·220		+0·284
Mean, excluding 1885, Aug. 26	+0·278	+0·220		+0·165

Observer, A. D. (0".00.)

1886, May 10	+0·12	+0·07	+0·14	+0·09
	+0·09		+0·06	+0·09
May 27	+0·20	+0·15	+0·20	+0·15
	+0·18	+0·18	+0·10	+0·15
Mean	+0·148	+0·140	+0·125	+0·120

Observer T. (−0".13.)

1885, Aug.	+0·12			+0·11
	0·07			0·14
	+0·08			+0·13
1886, May 27	−0·07	−0·10	+0·03	−0·08
	−0·09	+0·01	+0·07	−0·11
Mean	+0·030	−0·045	+0·070	+0·038
Mean, excluding 1885, Aug. 26	−0·060	−0·045	+0·070	−0·095

Observer, L. (−0".01.)

1886, May 18	+0·15	+0·15	+0·13	+0·18
	+0·11	+0·16	+0·16	+0·13
May 27	+0·09	+0·02	+0·01	+0·16
		+0·03	+0·09	
		+0·09	+0·11	
Mean	+0·117	+0·090	+0·100	+0·157

Observer, H. (+0ˢ·23.)

	Apparent Motion *l.* E.	Apparent Motion *l.* W.	Apparent Motion *r.* E.	Apparent Motion *r.* W.
	s	s	s	s
1885, Aug. 26	+0·41			+0·39
	0·38			0·36
	0·37			0·39
	0·41			0·42
	0·36			0·39
1886, May 18	+0·49	+0·54	+0·41	0·51
				+0·47
May 27	+0·36	+0·19	+0·21	+0·40
	+0·28	+0·20	−0·22	+0·32
Means	+0·383	+0·310	+0·280	+0·406
Means, excluding 1885, Aug. 26	+0·377	+0·310	+0·280	+0·425

Observer, S. D. (−0·16.)

1885, Aug. 26	+0·17			+0·44
	+0·15			0·19
	+0·32			0·10
	+0·01			0·18
	+0·13			+0·09
Mean	+0·156			+0·200

Observer, R. (+0·03).

1886, May 9	+0·07	+0·26	+0·21	+0·19
	+0·01	+0·24	+0·19	+0·21
Mean	+0·050	+0·250	+0·200	+0·200

The results for 1885, August 26, have been separated from the others in the second set of means for each observer, because the reversion-prism eyepiece was not used on that day, and also because the general working of the instrument on this first occasion was not quite so satisfactory.

After these preliminary measures some time was spent in making better general arrangements before any detailed investigation was undertaken. Among other things it was considered advisable to use a different form of chronograph. With the one used for the above observations and for ordinary star work, a record consists of a single puncture only, made on drawing-paper by a sharp pricker, there being no sensible difference between an almost instantaneous tap and one where the contact is continued for a considerable fraction of a second;

but it was felt to be desirable in the present instance to have a record of both the make and break of a contact. Accordingly a small chronograph, by Krille, which had been used for mechanical registration was adapted to electrical registration. The records are made by two pens which mark continuous lines round the barrel, except when drawn aside (one to the right and the other to the left) by the electro-magnets. It is found most convenient for reading off the transits to adjust the pens both to the same continuous line, placing one slightly in advance of the other. The distance between them affects every measure, and must therefore be very carefully observed. But by reversing the attachment of the electro-magnets, and placing that which was previously in the observing circuit now in the machine circuit, this distance between the pens enters into the observed measure of personal equation with the opposite sign; and this reversal which is performed by the observer in the middle of his observations on any day, thus eliminates any error in estimation of the distance.

Towards the end of June of the present year a systematic series of observations was undertaken by the four regular transit-circle observers for the determination of the change of personal equation with apparent rate of motion. The method of conducting the observations was as follows:—

A suitable artificial star on the brass plate having been selected, the corresponding stud is brought up from the west into contact with the stud corresponding to the first wire of the transit-circle by an assistant at the instrument, who turns the spindle of the driving-screw very slowly until the click of the electro-magnet on the chronograph is heard. This operation is generally repeated very carefully after the first click has indicated the approximate position for contact. When a satisfactory contact has been obtained, word is given to the observer at the transit-circle, who then bisects the artificial star with the first wire by means of the R.A. micrometer-screw, and records the reading. Two bisections are considered sufficient. The assistant at the instrument is then directed to pass to the second wire, at which the process is repeated, the stud being now bisected with the second wire of the transit-circle so that the reading of the R.A. micrometer is nearly the same. It would be exactly the same as the former if the interval between the portions of the two wire-studs with which the star-stud came in contact were the exact equivalent of the interval between the wires in the transit-circle. Observation shows that the wire-studs have been so well adjusted to these equivalent intervals that a condition to be presently mentioned is fulfilled. The above process is repeated for all the nine wires, and the mean of the 18 nearly equal readings (2 for each wire) of the R.A. micrometer is then taken. If now the micrometer be set to this mean reading, which for the moment we will suppose to apply accurately to each of the 9 wires, and the plate carrying the artificial star and its stud be

set in motion from west to east, an observer with zero personal equation would record the transit of the star at each wire exactly at the same instant at which contact is made by the star-stud with the corresponding wire-stud, and the pens in the instrumental and observing circuits would be deflected simultaneously. If the pen in the observing circuit is deflected later than the other, the observer is considered to have a positive personal equation. The condition referred to above is that the bisection and contact should be for every wire very nearly simultaneous; otherwise the records of the observer and machine would be made at sensibly different points of the star's path, and it is possible that this might introduce small errors.

Before, however, any transits are observed in this way, the above process of "taking adjustments," as it has been called, is repeated for the other side of the studs; that is to say, the star-stud is brought up from the east, so that the artificial star moves towards the west and appears to the observer to move towards his right. Another set of eighteen similar readings of the R.A. micrometer is thus obtained, the mean of which can be used in exactly the same way for setting the micrometer so that with reversed motion the ideal observer would record simultaneously with the machine. As a general rule, throughout the whole series of observations, the transits and adjustments were made in corresponding pairs with motion E and motion W.

After the observations for "adjustment" a number of transits —generally about a dozen with each direction of motion—were taken, the rate of motion being changed after every pair. This rate is controlled by the position of the brass disc on its spindle; and the spindle is graduated in twentieths of an inch to the right and left of a zero which corresponds to zero rate of motion. It was found by preliminary experiments that if the brass disc be set to the reading $22^{d}\cdot0$, the apparent rate of motion of the artificial star is the same as that of an equatorial star, and accordingly the following settings of the spindle were selected for trial: $33^{d}\cdot0$, $22^{d}\cdot0$, $16^{d}\cdot0$, $11^{d}\cdot0$, $6^{d}\cdot0$, $3^{d}\,0$. The first of these corresponds to a rate half as large again as that of an equatorial star, while the remaining settings correspond to the rates of motion of stars at N.P.D. 90°, 43½°, 30°, 15°, and 9° respectively. The last of these readings was after a few trials discarded as inconveniently slow for use in the present investigation. The succession of readings on any day was selected arbitrarily, so as to avoid any possible influence of systematic change of rate. Between separate transits, while the disc was being carefully set on the spindle by the assistant at the instrument, the observer recorded several consecutive seconds on the chronograph to indicate the time value of the chronograph scale on the particular day. This was necessary because the chronograph was somewhat exposed to the wind, and controlled merely by a fan governor; and it was found impossible to avoid small changes of rate. The mean of all the scale values thus indicated on any day has generally been adopted for

the reduction of the observations on that day, but sometimes, where it is clear that the chronograph has changed its rate during the observations, the observations on that day have been separated into groups. In any case the influence of slight changes of rate in the chronograph on the result obtained is very small.

The clock used to give the second signals was the transit clock, Hardy, which stands directly behind the observer and ticks loudly. The observer can thus without much trouble note the whole time of transit of the star to the nearest second, and since 1887, Sept. 8, this has been made the practice. Information was thus accumulated, first, as to the accuracy of the correspondence between the spindle setting $22^d{\cdot}0$ and equatorial rate; and secondly, as to the legitimacy of the assumption that the rate at which the brass disc was driven varied directly as the distance from the centre of the circular plate. In both cases the result was satisfactory [see note (5) at the end of the paper].

After a number of transits had been observed, the 'adjustments' were repeated exactly in the same order as at first, and the set of observations was complete. The process of reading off the differences in time recorded by the observer and by the machine, and of reducing the observations, is so simple as not to require further explanation; and we may give at once the concluded results for absolute personal equation, arranged with the spindle setting as argument.

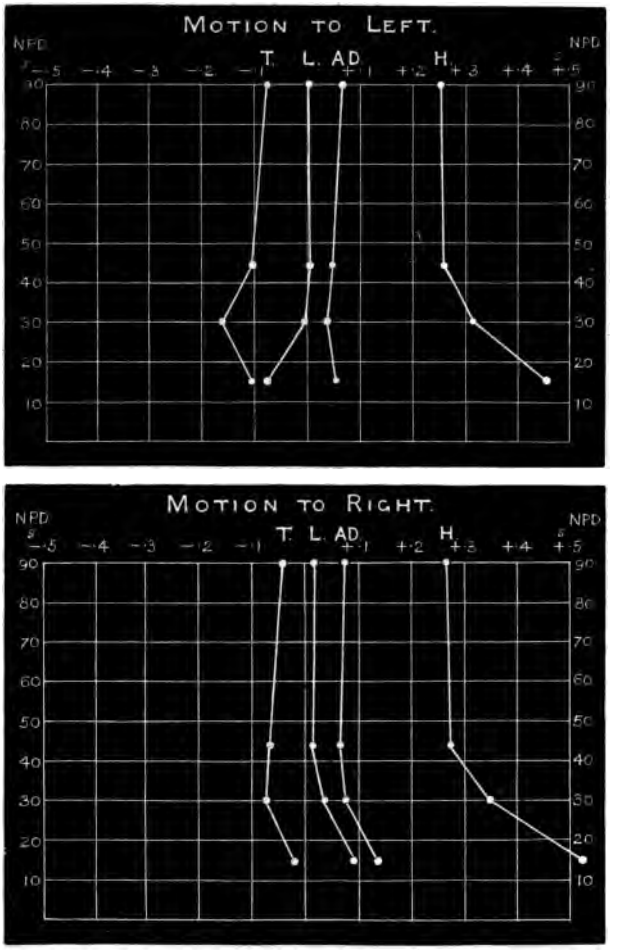
The probable error of a complete transit is found from the residuals to be $0^s{\cdot}030$, $0^s{\cdot}035$, $0^s{\cdot}044$, $0^s{\cdot}056$, $0^s{\cdot}093$ at the various spindle settings respectively; and from these numbers the probable errors given in the table have been deduced.

The number of transits observed in each case is given in brackets.

Absolute Personal Equation at Spindle Settings.

Obsr.	Direction of Motion.	33d		22d Equatorial Rate.		16d Rate at N.P.D. 43½°.		11d Rate at N.P.D. 30°.		6d Rate at N.P.D. 15°.	
		s	s	s	s	s	s	s	s	s	s
H. T.	*l*	−0·053	±0·013 (6)	−0·065	±0·015 (6)	−0·098	±0·020 (5)	−0·115	±0·028 (4)		
		−0·063	±0·013 (6)	−0·043	±0·015 (7)	−0·048	±0·020 (5)	−0·045	±0·028 (4)		
A. D.	*l*	+0·094	±0·007 (18)	+0·064	±0·008 (19)	+0·045	±0·011 (15)	+0·036	±0·014 (15)	+0·052	±0·026 (13)
	r	+0·072	±0·007 (17)	+0·075	±0·008 (19)	+0·065	±0·011 (15)	+0·076	±0·015 (14)	+0·137	±0·026 (13)
T.	*l*	−0·042	±0·006 (26)	−0·077	±0·007 (25)	−0·108	±0·009 (22)	−0·158	±0·014 (17)	−0·109	±0·024 (15)
	r	−0·044	±0·006 (26)	−0·036	±0·007 (25)	−0·062	±0·009 (22)	−0·069	±0·014 (18)	−0·019	±0·024 (15)
L.	*l*	+0·020	±0·006 (25)	+0·003	±0·007 (22)	+0·003	±0·010 (20)	−0·008	±0·012 (21)	−0·077	±0·022 (18)
	r	+0·013	±0·006 (24)	+0·021	±0·008 (20)	+0·014	±0·010 (20)	+0·036	±0·013 (20)	+0·093	±0·022 (17)
H.	*l*	+0·221	±0·007 (18)	+0·256	±0·007 (23)	+0·260	±0·012 (14)	+0·316	±0·013 (19)	+0·457	±0·023 (16)
	r	+0·234	±0·007 (19)	+0·267	±0·007 (23)	+0·274	±0·012 (14)	+0·349	±0·013 (19)	+0·528	±0·024 (15)

The following diagrams exhibit these results graphically for the four regular observers, and for rates of motion which occur in actual star observing. The whole width of each diagram represents a second of time, and the curve corresponding to each observer is to the right or left of the centre according as he is late or early in his record. The rate of motion is indicated by the corresponding N.P.D. for a real star.



The probable errors for a single transit do not increase directly as the rate of motion decreases; on reducing them to the equator the series of numbers becomes

0ˢ·045 0ˢ·035 0ˢ·032 0ˢ·028 0ˢ·025.

so that the observations at slower rates are more accurate. These "reduced" probable errors are represented very accurately by the formula

$$\text{Prob. error} = 0^{s}\cdot022 + 0^{s}\cdot0132 \times \frac{\text{spindle-setting}}{22},$$

so that the actual probable error is

$$0^{s}\cdot022 \times \frac{22}{\text{spindle-setting}} + 0^{s}\cdot0132.$$

Of these two quantities the first is a constant error in *arc*, and the second in time. The first probably represents the error of bisection of the star's image, and the second the error the observer is liable to make in trying to tap at a definite instant.

The probable error of the transit of an equatorial star observed over nine wires as found by Mr. Dunkin (*Monthly Notices*, vol. xxiv.) is $0^{s}\cdot017$; and the probable error of a result for right ascension is $0^{s}\cdot034$, the difference being due to errors in the determinations of the position of the transit-circle.

The determinations of personal equation above tabulated are fairly comparable with the second kind of measure; for here also various instrumental errors of adjustment are added to those of simple errors in transit observing. It is satisfactory to find such a close agreement between the deduced probable errors for a complete transit in the two cases.

The results for personal equation are checked at various points by other investigations:

A. The *relative* personal equations for clock-stars are investigated annually in the "Greenwich Observations." The standard observer is A. D. Till recently the direction of motion was always *l*, but the reversion-prism eyepiece has been used since 1884 June, for the observation of two clock-stars with apparent motion *r* on every fine night. The great majority of clock-stars are however still observed with the ordinary eyepiece, i.e. with apparent motion *l*, and the mean rate is a little less than equatorial—corresponding to a spindle setting of about 21^{d} instead of 22^{d}.

Selecting then the proper numbers from the above results for comparison with the relative personal equations we get

Obs.	Absolute P.E.	P.E. relative to A. D.	Difference = A. D.'s abs. P. E.
	s s	s	s
H. T.	$-0\cdot07 \pm 0\cdot015$	$-0\cdot15$	$+0\cdot08$
A. D.	$+0\cdot06 \pm 0\cdot008$	...	$+0\cdot06$
T.	$-0\cdot08 \pm 0\cdot007$	$-0\cdot13$	$+0\cdot05$
L.	$+0\cdot00 \pm 0\cdot007$	$-0\cdot01$	$+0\cdot01$
H.	$+0\cdot26 \pm 0\cdot007$	$+0\cdot23$	$+0\cdot03$
		Mean	$+0\cdot05$

The small discrepancies in the quantity found in the last column are quite consistent with a probable error of about $0^s{\cdot}010$ in each of the quantities between which it is the difference.

B. Besides these relative personal equations between different observers we have for comparison two sets of independently determined differences between the personal equations for the same observer with motion l and motion r respectively. The first set is deduced from comparison of clock errors obtained from observations with the transit-circle using the reversion-prism eyepiece.

Extracting in the same way the required differences $(r-l)$ from the table, for spindle reading 21^d we get

	From Machine results.	From Star results.	No. of Determinations.
	s s	s s	
H. T.	$+0{\cdot}027 \pm 0{\cdot}020$	$-0{\cdot}035 \pm 0{\cdot}011$	12
A. D.	$+0{\cdot}014 \pm 0{\cdot}012$	$+0{\cdot}010 \pm 0{\cdot}004$	70
T.	$+0\,042 \pm 0{\cdot}010$	$+0{\cdot}063 \pm 0{\cdot}012$	28
L.	$+0{\cdot}017 \pm 0{\cdot}011$	$+0{\cdot}020 \pm 0{\cdot}004$	72
H.	$+0{\cdot}011 \pm 0\,011$	$+0{\cdot}010 \pm 0{\cdot}004$	85

The number of determinations given in the last column indicates the number of nights on which clock-stars were observed with the reversion-prism. Usually two were observed on each night, but the transits were generally over four wires only. The probable errors are deduced from the residuals of the results for each night.

The second set of measures of the same quantity for stars moving rather more slowly was made with the altazimuth, the same star being observed at practically the same transit with both directions of apparent motion.

Taking out the differences for spindle reading 16^d as most suitable for comparison, we have for differences $(r-l)$:

	From Machine results.	From Altaz. results.
	s s	s s
H. T.	$+0\,050 \pm 0{\cdot}022$	$+0\,041 \pm 0\,020$
A. D.	$+0{\cdot}020 \pm 0{\cdot}011$	$+0{\cdot}030 \pm 0{\cdot}012$
T.	$+0{\cdot}046 \pm 0{\cdot}010$	$+0{\cdot}039 \pm 0{\cdot}017$
L.	$+0{\cdot}011 \pm 0{\cdot}010$	$+0{\cdot}047 \pm 0{\cdot}013$
H.	$+0{\cdot}014 \pm 0{\cdot}011$	$-0{\cdot}015 \pm 0{\cdot}009$

The agreement may be therefore considered satisfactory.

Returning to the consideration of the table of absolute personal equations, the chief point to be considered is the effect these small differences, hitherto neglected, would have on the Greenwich right ascensions. As regards clock-stars, whose rate of motion varies from that corresponding to spindle setting $22^d{\cdot}0$ (equatorial) to $17^d{\cdot}3$ (α *Lyræ*), it appears that two of the regular observers, L. and H., do not vary in habit between these limits, but that the

other two change nearly $0^{s}\cdot02$ and $0^{s}\cdot03$ in the same direction, so that the mean of the four observers would give correct results within $0^{s}\cdot01$ for the whole range.

As regards the stars catalogued, some of which move slowly and some have reversed direction of motion, the average effect is not quite insensible, the mean personal equation for the four observers being as below :—

N.P.D.		90°	43½°	30°	15°
Motion	*l*	+0·062	+0·050	+0·047	+0·081
„	*r*	+0·082	+0·073	+0·098	+0·185

There does not appear to be any general law representing the change of personal equation with rate. We might suppose the personal equation to be made up partly of error of bisection and partly of a constant error in time, either deliberate or unconscious. We should expect the latter not to vary with the rate or direction of motion, and the former to vary inversely as the rate and to change sign with the direction of motion. This is fulfilled approximately for all the observers except H., whose "error of bisection" amounting to nearly $1''\cdot0$ does not change sign with the direction of motion; so that in this case the observer apparently waits until the star has travelled about $1''$ past the wire—whatever be the direction of motion—and then "hangs fire" for about $0^{s}\cdot2$ before the record is complete. Such a well-marked exception rather precludes generalisation.

The quantities to be measured are all so small that their determination is originally liable to several sources of systematic error. The following notes on some special points may be of interest :—

(1) *Systematic error in reading off the transits.*—With the exception of two occasions, on which the observer read off his own transits, the differences were all read off by Mr. Downing. Any systematic error would then be presumably common to the whole series. But the precaution adopted of interchanging the circuits in the middle of the observations almost certainly eliminates any error of this kind. For instance, if Mr. Downing reads off every distance on the chronograph too large by $0^{d}\cdot01$ of the scale (each of the ink lines defining this distance is several times this quantity), the first group of deduced personal equations would be all too large by $\frac{0^{s}\cdot007}{S}$, where S is the ratio of the spindle setting to $22^{d}\cdot0$; but the second group would be all too small by the same quantity, and hence this error is practically eliminated in the mean result for each day.

(2) *The error in measurement of the distance between the pens* has been already referred to, and is eliminated in the same manner as in (1).

(3) *Permanence of the positions for contact between the studs.*—This is one of the most vitally important points in the working of the instrument, and one of the most satisfactory. The studs

are cylinders carefully rounded at the ends, so that the contact surfaces are approximately hemispheres. The upper stud is lowered until it will touch one of the lower set when about $0^{in}\cdot01$ (corresponding to about 3″) to the left or right of it; and consequently remains in contact with it for about $0^{in}\cdot02$ as it is carried over it. There is accordingly a slight lifting of the plate carrying the artificial star whenever one of the studs attached to it passes over one of the fixed studs; but so long as the above approximation of the studs is not exceeded, no appreciable interruption to the smoothness of the transit is discernible. Had this been the case, the difficulty could have been got over by giving the star-stud a small freedom of motion in a vertical direction relatively to the plate, the attachment being made by means of a spring instead of being rigid. But no such arrangement is found necessary, for the jerkiness in transit, noticeable when the duration of contact is large, disappears when it is adjusted as above to a total length of about $0^{in}\cdot02$ (corresponding to about 6″) in the transit-circle telescope; or, in other words, when the difference of readings of the R.A. micrometer for bisection of the artificial star when its stud is brought into contact from the left and right respectively is about $0^{r}\cdot400$. The mean value of this quantity found from all the observations is $0^{r}\cdot470$. On the other hand, if the length of contact is initially adjusted to much less than this, the contact is liable to fail after a number of transits owing to a little rubbing down of the points, or slight strain, or possibly some electrical action at the points of contact. Such changes are detected by measurements of the length of contact registered in transit, and by comparison of the adjustments taken after the transits with those taken before; and the position of a single stud for contact is rarely found to vary as much as $0^{in}\cdot005$ (corresponding to 1″·5). In preliminary experiments with the machine the changes had been somewhat larger and much more irregular, but from experiments made by Mr. Lewis, June 10–22, a large part of the disturbance was traced to the Sun's heat when sunlight was used to illuminate the star, the Sun's rays having also fallen on the studs, no doubt causing irregular expansion. On taking care to screen these portions of the instrument, the changes were immediately reduced in magnitude, and part of the apparent irregularity still remaining is no doubt error of observation. It is found, however, that the mean effect is a slight shortening of the contacts, the action being evenly distributed at the two ends, as might be expected from the symmetrical arrangement. The mean of this "wear" on the 32 days of observation is 0″·33 on the right and 0″·36 on the left, or a total shortening of $0''\cdot69 = 0^{in}\cdot0023$ in the whole length of a contact. On one day only was the mean wear for the 9 studs so much as $1''\cdot5 = 0^{in}\cdot005$, and on many days it was insensible.

Since the R.A. micrometer is set throughout the transits to readings determined by the first set of adjustments, the effect of

this receding of the contacts, which a discussion of the lengths of contact registered in transit shows to be gradual, is to attribute to the observer a gradually increasing personal equation, and a small correction becomes requisite. Where the total change is so small, however, it was considered sufficient to correct the transits as though the true position for contact were throughout the mean of those indicated by the two sets of adjustments.

(4) The distance between positions for contact on the right and left, i.e. the length of contact, is also registered on the chronograph. It is interesting to compare the value of this length as recorded by the deflection of the chronograph pen when the stud is in continuous motion with the value obtained by means of the R.A. micrometer in the position of rest. Special observations were taken with this object on June 22 and June 27, and the observations made on several subsequent days have been also discussed.

The following table shows the mean value of the length of a contact for one stud, as shown by the "adjustments" (in second column) and from registers on the chronograph for both directions of motion in the next column:—

Date.	Adjustments.	Transits.
	s	s
June 22	5·81	5·65
27	6·22	5·70
July 18	5·99	5·47
21	4·86	4·98
Aug. 1	4·82	5·58
Sept. 8	2·90	4·64
9	6·25	6·47
Mean	5·26	5·70

The small difference thus indicated is readily explicable on the assumption of a very slight sticking together of the studs for a small period longer than consistent with absolutely uniform motion. It was expected that such a sticking would have a constant time-value, and thus affect the more rapid rates of motion relatively to the slower. The observations on available days were accordingly collected under the various rates of motion with the following result:—

Spindle Setting.	Length of Contact.
d	s
33	5·36
22	5·42
16	5·58
11	5·50
6	5·30
Adjustments	4·96

There is thus no great difference between the duration of contact for slow and quick rates.

Part of this small discrepancy between measures at rest and in motion is possibly due to systematic error in reading off the chronograph intervals.

(5) The correspondence of the spindle setting $22^{d}\cdot0$ to equatorial rate has been carefully tested. On the earlier days one of the intervals between the wires of a transit was read from the chronograph. The equatorial value of this interval is $2^{s}\cdot811$. The mean value of this interval in time for the various rates of motion is as follows:—

d	d	d	d	d	d
33·0	22·0	16·0	11·0	6·0	3·0
s	s	s	s	s	s
1·801	2·753	3·691	5·404	9·913	20·650

or, reduced to the corresponding value at reading $22^{d}\cdot0$,

s	s	s	s	s	s
2·702	2·753	2·684	2·702	2·704	2·816

To obtain the second line it is assumed that the rate varies inversely as the spindle setting.

It was found, however, that, owing to the variations in rate of the chronograph, this was not a satisfactory method of measuring the rate of transit. The individual observations show large discrepancies, which would amply explain the above small differences in the means. The practice mentioned above was subsequently adopted of observing the whole time of transit to the nearest second. The mean results are as follows:—

Spindle setting	d 33	d 22	d 16	d 11	d 6
	s	s	s	s	s
Motion *l* ...	19·08	27·81	37·93	54·02	96·88
Motion *r* ...	18·81	27·91	37·92	54·36	100·09

or, reducing to reading $22^{d}\cdot0$,

	s	s	s	s	s
l	28·62	27·81	27·69	27·01	26·15
r	28·22	27·91	27·68	27·18	27·02

The equatorial interval of the transit wires being $27^{s}\cdot642$, the correspondence of the setting 22^{d} to equatorial rate may be considered satisfactory.

Note on the Probable Errors of the Star Places of the Argentine General Catalogue for 1875, and the Cape Catalogue for 1880. By A. M. W. Downing, M.A.

As a supplement to my paper on the star places of the Argentine General Catalogue for 1875, and the Cape Catalogue for 1880, printed in the *Monthly Notices* for last June, the following values of the probable errors of a difference of the catalogue places at different N.P.D.s. may be of interest. In the calculation of these probable errors it has not been thought necessary to make use of all the available material, but only of that resulting from the comparison of the places of stars of R.A. 0^h–1^h, 6^h–7^h, 12^h–13^h, and 18^h–19^h.

The following table gives the results of the computation :—

N.P.D.	No. of Stars.	Probable Error of a Single $\Delta\alpha$	Probable Error of a Single $\Delta\alpha$ sin N.P.D.	Probable Error of a Single $\Delta\delta$
° °		s	s	″
90–100	38	±0·050		±0·76
100–110	36	±0·064		±0·62
110–115	91	±0·048	±0·052	±0·57
115–120	194	±0·054		±0·51
120–125	207	±0·059		±0·56
125–130	194	±0·068		±0·56
130–135	200	±0·065	±0·051	±0·54
135–140	181	±0·074		±0·46
140–145	194	±0·089		±0·47
145–150	178	±0·084	±0·047	±0·50
150–155	133	±0·088		±0·48
155–160	93	±0·111	±0·041	±0·55
160–165	84	±0·127		±0·71
165–170	63	±0·201	±0·043	±0·52
170–180	47	±0·291	±0·025	±0·62

The mean value of the probable error of a single $\Delta\alpha$ sin N.P.D. is $\pm 0^s{\cdot}047$; and, assuming that the star places in the two catalogues are equally free from accidental errors, we find that the probable error of a R.A. in either $= \pm 0^s{\cdot}033$ expressed in equatorial time. The mean value of the probable error of a single $\Delta\delta$ is $\pm 0''{\cdot}55$; and, on the same assumption, it follows that the probable error of a N.P.D. in either catalogue $= \pm 0''{\cdot}39$. It appears, however, from Herr Backlund's investigations (*V. J. S.* 20 Jahrgang, III. Heft) that the probable errors of a single Cape observation in R.A. and N.P.D. are $\pm 0^s{\cdot}046$ cosec N.P.D. and $\pm 0''{\cdot}61$ respectively, and as each place in the Cape Catalogue depends, on the average, on 3 observations, we have the probable

error of a R.A. in the Cape Catalogue = $\pm 0^s{\cdot}027$ cosec N.P.D., and the probable error of a N.P.D. = $\pm 0''{\cdot}35$. Combining these values with the probable errors of a single $\Delta\alpha$ sin N.P.D. and a single $\Delta\delta$ given above, it appears that the probable errors of a R.A. and N.P.D. of the Argentine General Catalogue are $\pm 0^s{\cdot}038$ cosec N.P.D. and $\pm 0''{\cdot}42$ respectively.

On the Reduction of Star Places by Bohnenberger's Method.

By Professor Truman Henry Safford.

Every astronomer who has had much to do with the reduction of star places from one epoch to another is aware that in case the star be very near the pole, or the epochs very distant, the method invented by Bohnenberger must replace the ordinary employment of annual precessions and secular variations.

It is easy enough to see that when the product of the interval by the tangent of the star's declination reaches a certain amount the precession series is no longer convergent. If I can rely upon my remembrance of a mathematical investigation found in many text-books, the series

$$1-\tfrac{1}{3}+\tfrac{1}{5}-\tfrac{1}{7}+\tfrac{1}{9}-\tfrac{1}{11}, \text{ etc. for } \tfrac{1}{4}\pi = {\cdot}78539\ldots$$

is just on the line between convergence and non-convergence; and when the series, by which the right ascension of a star is expressed in terms of the time, contains as a part of itself a series of this degree of convergence it is no longer practicable to use it.

From Bessel's investigation on pages x and xi of the introduction to the *Tabulæ Regiomontanæ*, one can readily enough see that a star's right ascension as a function of the time contains terms of the form

$$\begin{aligned} & tn \tan\delta \sin\alpha \\ & + \frac{t^2n^2}{2}\tan^2\delta \sin 2\alpha \\ & + \frac{t^3n^3}{3}\tan^3\delta \sin 3\alpha \\ & + \frac{t^4n^4}{4}\tan^4\delta \sin 4\alpha. \\ & + \&c. \end{aligned}$$

together with other terms multiplied by the same powers of $\tan\delta$, but lower power of the time. The terms here given are those which determine the convergence when $\tan\delta$ is very great.

If, now, $tn \tan\delta = 1$ we shall have a series which exhibits precisely the same kind of lack of convergence as the well-known numerical arc which I quoted before.

As n is roughly $20''$ or $\frac{1}{10000}$ of radius, it is plain that this

absolute failure of convergence takes place when $t \tan \delta$ is about 10,000; or for a star 1° from the pole is about 180 years.

Using similar considerations I have been in the habit of selecting the epochs for the use of Bohnenberger's formula as follows.

We have tables for the secular variation, and for the term multiplied by the third power of the time. While these tables are not quite complete enough for close polar stars they are a very great help in checking calculations, and it is easy enough to use them or to calculate the terms depending upon the third, and by their variations from year to year those depending upon the fourth power of the time. So that when the term

$$\frac{t^5 n^5}{5} \tan^5 \delta \sin 5a$$

is insensible, it is not necessarry to employ the trigonometrical formula.

But it will be safer not to consider the sine of five times the right ascension as a factor; as, when it is casually small, the next factor sin $6a$ may be large; and we may require

$$\frac{(tn \tan \delta)^5}{5}$$

as the quantity to be made $0''{\cdot}01$ of arc. We shall then have

$$\frac{tn \tan \delta}{206264''{\cdot}8} = \sqrt[5]{\frac{0''{\cdot}05}{206264''{\cdot}8}},$$

or

$$5 \log \frac{tn \tan \delta}{206264''{\cdot}8} = 3{\cdot}38455 - 10,$$

or

$$\log \frac{tn \tan \delta}{206264''{\cdot}8} = 8{\cdot}67691 - 10,$$

or

$$\log tn \tan \delta = 3{\cdot}99134.$$

Taking $\log n$ for 1900, according to Struve = 1·30216, we shall have

$$\log t \tan \delta = 2{\cdot}68918,$$

or

$$t \tan \delta = 488{\cdot}9 \text{ years.}$$

For *Polaris* in 1887, whose declination is 88° 42′·5, the interval here indicated is about 11 years. That is to say, the right ascension of *Polaris* can now be carried forward or back 11 years by the use of the first four differential coefficients of the right ascension with respect to the time; so that a trigonometrical computation for every 20 years is amply sufficient to afford a check at the beginning of one period and the end of the next preceding.

For a star in the declination 88° 58′ the single interval t is rather less than 9 years, and the double rather more than 17; so that to compute a series of places from year to year of λ *Ursæ Minoris* or Groombridge 1119 = B.A.C. 2320 (*Connaissances des Temps*) the trigonometrical computation should be employed every 16 years at least, to make sure of 0″·01 in the right ascension. Similar consideration should be applied to find out when other terms become insensible, or less than 0″·01.

Suppose we employ the general formula

$$\frac{1}{p}\left(tn\tan\delta\right)^p = 0''\cdot01,$$

making p successively 3, 4, 5 . . . and we shall have

$$t\tan\delta = \left(\frac{p\times 0''\cdot01}{206264''\cdot8}\right)^{\frac{1}{p}}\frac{206264''\cdot8}{n},$$

as given in the following little table:—

p	$t\tan\delta$ years.	t for *Polaris*, $\frac{t}{y}$	t for λ *Ursæ Minoris*, $\frac{t}{y}$
3	54·1	1·2	1·0
4	215·9	4·9	3·9
5	488·9	11·	8·9
6	837·3	19·	15·
7	1225·	28·	22·
8	1625·	37·	30·
9	2021·	46·	37·
10	2403·	54·	44·

The formula is

$$\log t\tan\delta = 4\cdot01226 - \frac{7\cdot31443}{p} + \frac{\log p}{p}.$$

Practically, anyone who attempts to use the higher terms up to the 10th in reducing star places will find it a very uncertain and perplexing matter, far less easy than the judicious employment of the trigonometrical formulæ.

If in any given case, like that of λ *Ursæ Minoris* for example, it is desired to extend the series to the 5th term, this can be practically accomplished as follows:—

The highest part only in power of $\tan\delta$ of the 4th term will be

$$t^4\frac{n'^4}{4}\tan^4\delta\sin 4\alpha,$$

and that of the 5th term

$$t^5\frac{n'^5}{5}\tan^5\delta\sin 5\alpha,$$

which last will doubtless be sufficiently approximate to the total

value of the term for 10 years, as it cannot exceed 0″·02 for this period, which is at any rate quite insensible when reduced to the parallel of the star.

If, indeed, we choose to take 0″·01 *after reduction to the parallel* as our limit of accuracy in computation, we may practically employ the t corresponding to a term farther along in the series than we intend to employ; but a skilled computer will soon find the practical limits beyond which these theoretical arcs may be extended without damage.

In this way it will be seen that for stars not very near the pole the terms beyond the ordinary "secular variation" soon become sensible. As a long and valuable memoir by two Austrian astronomers, Herz and Strobl, which I have seen but do not yet possess, relates, in part, to this subject in its application to Auwers's fundamental catalogue, I will only say here that for $\delta = 45°$, t should not be more than 54 years to secure (without examination of the special case) the insensibility to less than 0″·01 of the error caused by omitting the third term. Professor Argelander in fact calculated these values for all declinations over 39°; his greatest interval was 120 years (1755–1875), which agrees well enough with my table.

The actual calculation by Bohnenberger's method requires the use of three quantities $z+\lambda$, $z'-\lambda'$, and θ, which depend partly upon the epoch from which, and that to which, the reduction is effected; and partly upon the epoch taken as the fundamental one for the precession, constants, and so forth.

In the use of Struve's precessions, now entirely general, the fundamental epoch is of course 1800. I have used 1855 as the general date from and to which the places are to be reduced, following Carrington for reasons of convenience. The same date had been also adopted by Dr. Gould, and was afterwards used by Professor Boss; and I have not thought it worth while to change at present to a later epoch. Carrington's catalogue affords (for all close northern polars) approximate positions at once for this year; it also lies between the two Radcliffe catalogues, which can by their own data be readily reduced to it; and is nearly identical with the general mean date (by weight) of the existing catalogues of these northern stars. The method which I employ makes this a convenience, and at the same time renders it needless to select a later date for the constants $z+\lambda$, &c.

If a change is to be made in this respect I think the next year adopted should be 1900, so far as these quantities are concerned. As a matter of curiosity I desired to follow the changes in the place of *Polaris*, and so computed some values of their constants up to 2100. In the table which follows I give them; those to be added to the right ascension are expressed in time. This is now rendered a matter of the greatest convenience by the admirable tables of the previously mentioned astronomer

Norbert Herz,* published by Teubner at Leipzig in 1885; a book which I find indispensable in all computations of precession.

At a future time I intend to publish the results of my discussion of the relative movements of *Polaris* and the north pole; it is enough to say here that the nearest approach takes place, according to my calculation, some time in the year 2102 at a north declination of 89° 32′ 23″; the star will reach 89° about 1944, and be for about 300 years within a degree of the pole.

The tables have been pretty thoroughly checked in various ways. They were computed for every twenty years with seven-figure logarithms (Schrön's), using the additional marks to indicate the half of the seventh decimal, and carrying the interpolations to the eighth figure; and were compared with values given by Dr. Gould and Professor Boss for various dates, and by differences for intermediate years.

Moreover, the position of *Polaris* was brought up to 1900 from 1855, and then to 2000 and 2100 by both tables, with very slightly different results; in neither co-ordinate more than 0″·002 in arc of a great circle. I had no ten-figure table at hand, but it hardly seemed necessary.

The simplest method of discussing a long series of polar-star places collected from the various catalogues is to assume a position for 1855·0 from a careful preliminary discussion; reduce it to the various epochs of Table I. for which there are observations, and compare with observations. The benefit of this process is that defective or erroneous right ascensions do not affect the reductions of the declination; while the error in the assumed place is readily found and allowance made if necessary.

TABLE I.—*For Bohnenberger's Method.*

(The reductions are *from* 1855·0 to the tabular dates.)

Date.	$z+\lambda$	$z'+\lambda'$	θ
	m s	m s	′ ″
1755	−2 33·588	−2 33·506	−33 25·987
1760	2 25·909	2 25·835	31 45·671
1780	1 55·196	1 55·142	25 4·423
1790	1 39·841	1 39·791	21 43·816
1800	1 24·486	1 24·438	18 23·202
1810	1 9·133	1 9·083	15 2·603
1815	1 1·456	1 1·404	13 22·305
1820	0 53·780	0 53·724	11 42·010
1828	0 41·497	0 41·436	9 1·542
1830	0 38·427	0 38·364	8 21·426
1835	0 30·751	0 30·683	6 41·137
1840	0 23·075	0 23·001	5 0·849

* *Siebenstellige Logarithmen der trigonometrischen Functionen für jede Zeitsecunde*, 186 pp. 8vo.

Date.	$z+\lambda$	$z'+\lambda'$	θ
	m s	m s	″
1842	0 20·005	0 19·928	4 20·735
1845	0 15·400	0 15·318	3 20·564
1850	0 7·724	0 7·635	1 40·281
1852	0 4·654	−0 4·562	−1 0·168
1855	−0 0·049	+0 0·049	0·000
1860	+0 7·627	0 7·733	+1 40·279
1864	0 13·766	0 13·881	3 0·500
1865	0 15·301	0 15·418	3 20·555
1870	0 22·976	0 23·104	5 0·830
1872	0 26·046	0 26·178	5 40·939
1875	0 30·651	0 30·790	6 41·102
1880	0 38·325	0 38·477	8 21·372
1885	0 46·000	0 46·165	10 1·640
1890	0 53·674	0 53·853	11 41·905
1900	1 9·022	1 9·232	15 2·428
1920	1 39·715	1 39·997	21 43·445
1940	2 10·407	2 10·772	28 24·422
1960	2 41·096	2 41·558	35 5·355
1980	3 11·782	3 12·354	41 46·244
2000	3 42·467	3 43·161	48 27·085
2020	4 13·149	4 13·978	55 7·879
2040	4 43·829	4 44·807	1° 1 48·622
2060	5 14·507	5 15·646	1 8 29·312
2080	5 45·182	5 46·496	1 15 9·947
2100	6 15·856	6 17·357	1 21 50·525

TABLE II.—*For Bohnenberger's Method.*

(Reduction from 1900 to tabular date.)

Date.	$z+\lambda$	$z'+\lambda'$	θ
	m s	m s	′ ″
1920	+0 30·532	+0 30·926	+ 6 41·025
1940	1 1·223	1 1·701	13 22·013
1960	1 31·912	1 32·486	20 2·962
1980	2 2·598	2 3·282	26 43·872
2000	2 33·281	2 34·088	33 24·739
2020	3 3·962	3 4·905	40 5·562
2040	3 34·641	3 35·732	47 46·339
2060	4 5·318	4 6·570	53 27·068
2080	4 35·992	4 37·419	1° 0 7·746
2100	5 6·665	5 8·278	1 6 48·373

The formulæ for reductions from 1855 or 1900 to any tabular date are (here α, δ are the position for the fundamental epoch, α', δ' those for the tabular date).

$$\begin{aligned} A &= \alpha + z + \lambda \\ m \cos M &= \cos\delta \cos A \\ m \sin M &= \sin\delta \\ \cos\delta' \sin A' &= \cos\delta \sin A \\ \cos\delta' \cos A' &= m \cos(M+\theta) \\ \sin\delta' &= m \sin(M+\theta) \\ \alpha' &= A' + z' - \lambda'. \end{aligned}$$

Other formulæ giving the same results are frequently employed, but I find these on the whole the most convenient.

On the Orbit of p Eridani. By J. E. Gore.

In previous investigations on the orbit of this southern binary star it seems to have been assumed that Dunlop's measure in 1825 is probably erroneous, owing to the difficulty experienced in making it fit satisfactorily into an orbit with the other measures. Assuming, however, the approximate correctness of Dunlop's measure, and using some recent measures by Mr. Tebbutt (N.S.W.), and by Mr. Pollock at the Sydney Observatory, I have computed the following provisional elements:—

Elements of p Eridani.

P = 302·37 years.	$\Omega = 135°\ 0'$ (1870·0).
T = 1823·55.	$\lambda = 240°\ 0'$.
$e = 0·674$.	$a = 6''·96$.
$\gamma = 38°\ 31'$.	$\mu = -1°·19$.

The following is a comparison between the recorded measures and the positions computed from the above elements. The computed position-angles have been corrected for the effect of precession to 1870·0.

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	"	"	"
1825·96	Dunlop	343·1	348·6	−5·5	2·5 (est)	2·12	+0·38 ±
1835·00	Sir J. Herschel	302·3	303·9	−1·6	3·65	3·17	+0·48
1845·88	Jacob	276·0	276·7	−0·7	4·16	4·13	+0·03
1846·35	,,	276·5	275·8	+0·7	4·32	4·18	+0·14
1849·82	,,	270·0	269·5	+0·5	...	...	...
1850·80	,,	268·7	267·9	+0·8	...	4·51	...
1851·79	,,	266·4	266·3	+0·1	4·30	4·59	−0·29

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	″	″	″
1852·76	Jacob	264·8	264·8	0·0	4·14	4·66	−0·52
1853·96	Powell	263·2	263·0	+0·2	...	4·73	...
1856·09	Jacob	261·1	259·9	+1·2	4·70	4·87	−0·17
1857·96	„	258·1	257·4	+0·7	4·49	5·01	−0·52
1861·03	Powell	253·4	253·6	−0·2	4·86	5·22	−0·36
1870·92	Russell	242·1	242·8	−0·7	5·46	5·85	−0·39
1877·03	Ellery	237·3	237·3	0·0	(5·0)	6·19	(−1·19)
1878·19	Russell	237·0	236·3	+0·7	6·138	6·26	−0·122
1879·93	Hargrave	237·3	234·9	+2·4	5·44	6·37	−0·93
1880·45	Russell	234·7	234·5	+0·2	6·295	6·40	−0·105
1880·58	Tebbutt	233·6	234·4	−0·8	6·42	6·41	+0·01
1882·18	„	233·0	233·1	−0·1	7·01	6·53	+0·48
1885·19	„	230·5	230·8	−0·3	7·10	6·75	+0·35
1886·901	Pollock	229·9	229·6	+0·3	6·63	6·82	−0·19
1886·909	„	230·8	229·6	+1·2	6·85	6·82	+0·03

Further Researches on Stellar Parallax by the Photographic Method. By Professor C. Pritchard, D.D., F.R.S.

In my last communication to the Society I gave the results of an investigation of the parallax of the two components of 61 *Cygni*, each being referred to four comparison stars independently. These eight independent results cohere in a remarkable manner, and together furnish a mean value of the parallax identical with that derived from the determinations of Bessel and subsequent astronomers.

Encouraged by the hopefulness of this new method, I entered on the discussion of the parallax of μ *Cassiopeiæ* and of the Pole Star. The necessity, however, of improving the mechanism of the De La Rue equatorial, now much worn by long and honourable service, greatly interrupted the continuity of the work. Aided by the continued generosity of the original donor this instrument was ultimately restored to very effective order by Mr. Simms, and since its restoration the research has continued without avoidable interruption.

On each of fifty-three nights, four photographic plates were taken of μ *Cassiopeiæ*. The exposures varied from five to ten minutes. About 3 per cent. of these plates were found to be injured and unsuitable for the inquiry. This number of defective plates is so small that, in the work to be presently described, I have adopted the method of taking two impressions on the same plate slightly moved in position, and in this way both labour and expense are economised. Details of all these

researches will in due time be published by the University in a third fasciculus of the Oxford Observatory proceedings. Awaiting this publication I here give simply the results of the investigation.

Two suitable stars, here called (A) and (B), were selected as comparison stars, of approximately the 8th and 10th magnitudes. The resulting parallaxes are as follows:—

From star (A) $\pi = 0''{\cdot}0501 \pm 0''{\cdot}0270$.

From star (B) $\pi = 0''{\cdot}0211 \pm 0''{\cdot}0235$.

If a correction for the adopted value of the proper motion of μ be omitted, then the respective values are

From star (A) $\pi = 0''{\cdot}0677$.

From star (B) $\pi = 0''{\cdot}0429$.

These parallaxes are extremely small, and, taking into account the large proper motion of μ *Cassiopeiæ*, are interesting. Bessel, in 1816, investigated the parallax of this star by means of differences of right ascension on seventy nights, but he arrived at a *negative* value of $0''{\cdot}12$. It is, however, both proper and interesting to remark that this research and its result apply to a time long anterior to the introduction of the heliometer in 1829. In 1856, Professor Otto Struve obtained a parallax of this star by means of micrometrical comparisons, amounting to $0''{\cdot}342$; a quantity well within the compass of Bessel's method in 1816.

On reviewing the laborious processes adopted for the determination of the parallax of the preceding stars, it occurred to me that it would be a matter both of interest and importance to inquire what results would be obtained, had the measures been confined to a few nights only, when 61 *Cygni* and μ *Cassiopeiæ* were respectively at their greatest and least apparent distances from the comparison stars selected. Accordingly this method was applied first to 61 *Cygni*, when ten nights of maximum and minimum distance were selected from the entire group of eighty-nine nights. The result was a parallax of $0''{\cdot}4089$, as compared with $0''{\cdot}4321$ from the entire series.

The approximate identity of these results induced me to still further reduce the number of nights to five in the case of μ *Cassiopeiæ*, and these gave relatively to the two comparison stars mentioned above the respective parallaxes of $0''{\cdot}055$ and $0''{\cdot}095$, in place of $0''{\cdot}053$ and $0''{\cdot}021$. The probable errors, however, as was to be expected, are sensibly increased.

Bearing in mind the unavoidably approximate character of even the most elaborate investigations of stellar parallax, and especially when set side by side with the results obtained by this curtailed method, I have resolved (in ordinary cases) to abandon the very laborious processes applied in the case of 61 *Cygni*, and henceforth to limit the observations to five nights in each of four periods of the year, indicated by the position of the paral-

lactic ellipse. It is hoped that by this process the parallax of from ten to fifteen stars at the least will be determined within the year.

Forming my expectations from the experience of the past, I am led to hope that the parallaxes of all stars will in general be determinable by this method when they are not less than the thirtieth of a second of arc; for I find from the calculations of actual instances, that the probable error of a single night's measure of a "distance" does not sensibly exceed the tenth of a second; and inasmuch as the square root of the weight of π derived from the solution of a typical normal equation is 3·6, the probable error of π will not exceed the thirtieth of a second.

In the first instance I propose to apply this method systematically to all those stars between the magnitudes of $1\frac{1}{2}$ and $2\frac{1}{2}$, which attain at Oxford a sufficient altitude, and in fact it is already in course of application to α, β, γ *Cassiopeiæ*, and to γ and ϵ *Cygni*.

Certain cosmical relations cannot be safely inferred excepting from the parallaxes of numerous stars, and for such purposes *classes* of sufficiently approximate parallaxes will be more valuable than somewhat more accurate determinations in isolated cases.

I had hoped to have completed by this time the final determination of *Polaris* by the more elaborate process applied to 61 *Cygni*. The serious interruptions which have been already alluded to necessitate the continuance of the measures until June next. Meanwhile, I may mention that the curtailed process of selected nights has given a parallax amounting to 0″·052; a value which, according to Mr. Maxwell Hall, is close to the mean 0″·043 of all the determinations made by preceding astronomers.

Photographs of the Nebulæ 57 M. Lyræ; 27 M. Vulpeculæ; the Cluster 13 M. Herculis; and of Stars in Cygnus. By Isaac Roberts.

57 *M. Lyræ.*

Seven photographs of this annular nebula were obtained between July 14 and 31, 1887, with exposures varying between 10 and 60 minutes' duration. The enlargements (one 3 times and the other 25 times) which I now submit are from the negative taken on July 31, with an exposure of 20 minutes. Each of the negatives exposed for 15 minutes and upwards shows with much density the ring. The central star is also visible on each, though it is faintly seen on some; the light is therefore, photographically, very active. The interior of the ring is filled with faint nebulous matter, thus confirming the character given of it by Sir J. Herschel; but there is no evidence

of resolvability as suggested by the Earl of Rosse, and asserted by Secchi.

The photographs show the ring about the extremities of the major axis fainter than the remainder, and that there are protrusions somewhat beyond a line that would form the ellipse quite symmetrical.

Sir J. Herschel * states that the 11th mag. star following is distant about the breadth of the ring from the nebula, but the photographs show it to be less than half that distance removed.

The Earl of Rosse † shows filaments round the outer edge of the nebula which the photographs do not, but all the negatives clearly show the central star, which is not indicated by Sir J. Herschel or the Earl of Rosse. They refer to the internal nebulosity which by the photographs is much fainter than the star, yet neither of them has seen it, and, therefore, the suggestion that the star is variable receives here some confirmation.

27 M. Vulpeculæ.

Seven photographs of this nebula also were obtained between July 31 and October 10 this year, with exposures varying between 15 minutes and 2 hours' duration; but the atmospheric and other circumstances during the opposition this year were unfavourable to long exposures, and the light of the nebula is very feeble. Therefore this photograph taken on August 27 last, with exposure of 90 minutes (enlarged 15 times), does not exhibit the details that could be shown under good conditions; but it is clearly an elliptical nebula, and the drawing of it by Mr. Lassell in the *Memoirs* of the Society for 1866 (omitting the stars and internal details) agrees well with the photographs, and so also does the drawing by the Earl of Rosse in 1861.

Cluster 13 M. Herculis.

The two photographs (enlarged 3 times and 15 times) are from a negative taken, with an exposure of 60 minutes, on May 22 of this year. Sir J. Herschel and the Earl of Rosse have given drawings of this cluster, but as the positions of the stars in them are only roughly indicated, they cannot usefully be compared with the photographs. Sir J. Herschel says * there must be thousands of stars in it; it does not come up to a nucleus, has hairy-looking curvilinear branches, indicates a globular form not much denser at the centre.

The Earl of Rosse says ‡ it seems to have a dark streak across the bright part, a little above the centre; dark spaces seen through mist.

Several of these descriptions are confirmed by the photographs, but two prominent features are omitted by both observers, namely, the nebulosity of the individual stars and the cluster itself being involved in nebulosity.

* *Phil. Trans.* 1833. † *Ibid.* 1844. ‡ *Ibid.* 1861.

These features are best seen on the negatives, though they are also well shown on the enlargements.

Stars in Cygnus.

Admiral Mouchez presented to the Society four beautiful photographs, by the Brothers Henry, of stars in *Cygnus*. One of them taken on August 14, 1885, has A. R. $19^h\ 45^m$ and D. 35° 30′. On August 23, 1886, I took a photograph of the same sky space, and on August 14 this year again another. These have been enlarged 3 times, and they serve to illustrate what has frequently happened in my experience of stellar photography—that with similar plates, exposed to a given sky space for an equal length of time, and apparently with equal clearness of sky, there are surprising differences in the number of the stars that can at any time be photographed.

In the three photographs to which reference is here made these differences are remarkable, and to enable us to appreciate them, I counted one-eighteenth (17·75) of the stars upon corresponding areas on each plate respectively, and by measurements and calculations founded upon these data arrived at the following results :—

1st. The number of stars upon MM. Henry's plate in 1885 equal	3124
2nd. The number of stars upon my plate of 1886, having a sky area coincident with that of MM. Henry's plate equal	5023
3rd. The number of stars upon my plate of 1887 with coincident sky area equal	16206

The exposures in each case were of 60 minutes' duration, yet the third plate has upon it more than five times as many stars as the first.

These facts point out one of the difficulties that will be frequently met with by those who will be participating in the formation of the projected international photographic chart of the stars which is intended to include stars down to the 14th magnitude, with exposures of 15 minutes; but I am not here suggesting that the difficulties cannot be overcome. These discrepancies may be due to several causes, mechanical, chemical, and atmospheric, acting differently at different times.

On the Measurement of Celestial Photographs. (*Extract from a Letter to the President.*) By Isaac Roberts.

I wish to ascertain if some of the Fellows of the Society would be willing to engage in the scientific work of stellar photography by determining from negatives—

First. Stellar parallax.

Second. Stellar proper motion.

Third. Stellar photographic magnitudes.

Fourth. Stellar colour and variability.

Fifth. Stellar work not particularised above.

May I therefore ask you to communicate to the Fellows the offer that I should be willing to place in their hands such negatives as would enable a limited number of them to conduct with the necessary accuracy the investigations enumerated in these suggestions?

The essential equipment required by any worker would be: 1st, a good position micrometer; 2nd, a microscope of simple construction with 1-inch and 3-inch objectives, a sliding stage 7 inches × 7 inches (a plate of glass would do), and a reflecting mirror beneath it.

With such inexpensive appliances as here named astronomical work of the highest accuracy could be done, without the costly equatorial and transit instruments, and without the physical exposure at night which is unavoidable in using them.

I would supply the negatives free of cost, and only stipulate in return that each worker should have the necessary knowledge and perseverance to pursue the investigations he undertakes, and that he should communicate the results to the Society in a form acceptable to the Council.

1887, *November* 7.

On the Appearances presented by the Satellites of Jupiter during Transit, with a Photometric Estimation of their Relative Albedos, and of the Amount of Light Reflected from the Different Portions of an Unpolished Sphere. By Edmund J. Spitta.

Since their discovery by Galileo in 1610, the satellites of *Jupiter* have met with much attention, both from the mathematical as well as the physical astronomer. It is not the purpose, however, of this paper to deal with the former class of investigation, and only with so much of the latter as strictly relates to the appearances presented by the satellites during transit.

It is needless to state that during superior conjunction the satellites have from times most remote presented appearances not satisfactorily accounted for; appearances, too, which do not seem to apply equally to all the satellites, or even in some instances to the same satellite in two successive revolutions.

Passing over the first observation of the kind by Cassini in 1665, the next is recorded by Maraldi in 1707, who wrote two memoirs to the Paris Academy upon the subject, his interest having been excited by witnessing the third satellite transit as a dark spot on April 4, but as a white one during the next revolution on April 11. From this time up to the present date numerous observers, amongst whom might be mentioned

Dawes, have witnessed anomalous appearances of one or other of the satellites—the second being always excepted, as will be referred to hereafter—and their recorded observations are to be found in the *Monthly Notices*, and in the Astronomical or other scientific journals.

Speaking briefly, from a large source of recorded data, and from notes of my own, extending over several years, the phenomena may be summarised as follows:—It appears notably that as the fourth satellite approaches the disc of *Jupiter* it becomes rapidly and increasingly fainter, until arriving at contact. When once upon the limb, it shines with a moderate brilliancy for about ten to fifteen minutes, no sensible difference in such duration of brilliancy being noticeable whether before, during, or after opposition. Following this, it suddenly becomes lost to view; an obscurity which, so far as my personal observations go, will not yield to the powerful light-grasp of a ten-inch reflector. Remaining in this obscurity for another period of about ten to fifteen minutes, it again becomes visible, but now as a dark spot, which shortly grows darker and darker until it equals the blackness of its own shadow on the planet.

These phenomena are not found to be exhibited by the second satellite, however; for this moon it appears has never been seen otherwise than white during transit. After having searched the literature of the subject, and before coming to this conclusion, I invited, through the medium of the Astronomical Papers those possessing any records of abnormal phenomena of the satellites in the shape of unpublished notes to forward them to me. Several replies were received concerning the other satellites, but no observations concerning the second.*

The appearances of the first and third satellites, however, differ again from the second and fourth. The former during transit is sometimes a light-steel grey, and at others so dark as to nearly merit the name of black (see foot-note to Series 2 of the experiments that follow), having often been described as "dark brown" or "dark grey," whilst the latter satellite has been seen distinctly white, and also so black as to be compared with the appearance of the fourth.

Tabulated for future reference these phenomena during transit become—for the

Fourth. That it is fainter than others on approaching limb; bright for first ten to fifteen minutes of transit;

* The only exception to this remark may be found in a paper by Sir W. Herschel, read before the Royal Society, June 1, 1797, in which he states: "It will hardly be necessary to take notice of a single observation at 163°, as from the proximity of the satellite to conjunction a mistake in the estimation may easily take place." So, too, with another observation, in which he thought the satellite looked "ashy" in colour. It is more than probable these appearances were subjective, as will be the more readily understood after the contrast experiments have been gone into.

lost for about the same time; reappears as a dark spot, becoming jet black.

Second. Always bright during transit; brilliancy least affected on approaching limb of planet.

Third. Sometimes becomes lost, reappearing as a dark spot; at others, remains white throughout.

First. After becoming lost, usually turns one of the shades of grey to nearly black.

Towards the end of 1884 it was thought that possibly the peculiar appearance of the fourth satellite and the dark tints of the others were merely optical, and that if it were possible to devise some means or arrangement to shut off the background of *Jupiter*—if not entirely, for the greater part—that the white appearance of the satellite would be restored. Accordingly the occulting eyepiece (*Monthly Notices*, 1884–5, vol. xlv. page 91) was arranged, with which it was hoped to have tried the experiment; but although the mechanical action of the shutters in the focus of a Ramsden eyepiece left nothing to be desired, still, when sufficiently closed, diffraction phenomena put aside all possibility of examining the satellite. Two other oppositions of the planet were occupied in further examinations of the satellites, not only during transit, but also in most parts of their orbit; but none of the observations added to the pre-existing knowledge of the subject.

In the summer of 1886, however, it occurred to me that some experiments on the effects of contrast might be made to ascertain the proportions of light which two bodies must possess, so that the smaller should appear black when superimposed on the larger one. It was thought then that if the facts and figures thus experimentally obtained were found to coincide with the relative albedos of the satellites themselves as compared with *Jupiter*, it would not be unreasonable to suspect that the abnormal appearances presented during transit depended on functional idiosyncrasies of the eye itself rather than to physical peculiarities of the Jovian system.

The following experiments, divided into series, were organised and conducted by a friend and myself:—

The Experiments.

The ratio of *Jupiter* to his satellites in linear diameter, being assumed as about thirty to one, several discs one-eighth of an inch in diameter were punched out of pieces of cardboard, previously prepared by painting with one, two, or more coatings of Indian ink flooded on. A disc of pure white cardboard was also obtained, $3\frac{3}{4}$ inches in diameter, fixed on a support of dead-black material and placed at a distance of about sixty yards from the observing telescope, a three-inch Tulley. The little discs or artificial moons were each provided with fine wires, so that

they could be held in front of the larger disc in the full light of a very powerful 3-inch condensing magic lantern, provided with three $2\frac{3}{4}$-inch wicks. One observer, for the first half of the experiments, had charge of the moons, and placed them upon the disc in succession, at first according to their number of coatings of ink, and afterwards, in repeating the experiments, in an irregular order; whilst the second observer viewed the effects produced in the telescope. The moon that appeared grey on the large disc with the fewest coatings of ink was noted, and that also which appeared as black as its shadow. Especial care was taken that the plane of each moon was at right angles to the collimation axis of the observing telescope, and that it had the same inclination to the light as the others: a necessity which was found at an early period of the experiments to be a very essential feature in the general arrangements.

The observers then changed places and the results were compared, when it was found that no subjective or personal influence interfered with the power of repetition.

The next point to be ascertained was the difference of reflective power in the moons which had appeared grey and black (as they will hereafter be termed) when compared with one similar in size of white cardboard; in other words, to ascertain their relative albedos to the disc of cardboard which had formed the background.*

A Pritchard's photometer was obtained, being especially made by Sir Howard Grubb according to some suggestions afforded by the kindness of Mr. Plummer, of Oxford University Observatory, who carefully examined the uniformity of the wedge itself throughout its entire length and evaluated it also for magnitude, and who merits the writer's warmest thanks for placing his experience so liberally at his disposal. This was attached to the occulting eyepiece already referred to, in such a manner that its shutters could be utilised at the same time as the wedge.† Owing to the focal length of the Tulley telescope, as well as its mounting being found unsuitable for the present purpose, a $2\frac{1}{4}$-inch object-glass of specially short focus was obtained and mounted on a very firm cast brass stand. The tube had no movement in azimuth, save but for a very limited amount of adjustment, but changes in its position with respect to altitude were possible, and were ascertained by a vernier and circle. Clamping arrangements of the firmest description were added.

The original intention was to compare the moons in the same field one with the other at the same time, but, as related by Professors Pickering and Pritchard with respect to the photo-

* The best definition of albedo is Seidel's, who thus defines it: "Albedo is the proportion diffusedly reflected by an element of surface of the (solar) light incident on such element," which in other words is the "relative capacity for reflection of diffused light from equal areas."

† For information concerning other details connected with this arrangement of the Pritchard's photometer see *The Observatory*, No. 129, page 389.

metry of double stars, the peculiar errors which the presence of one object in the field produces on the appearances (photometrically) of another, on the one hand; and the loss in the intensity of the light which was found to take place from the centre to the edges of the beam of light proceeding from a smaller condensing lantern used in preference in these determinations to the larger one, on the other, rendered this method insecure.

To meet this difficulty an arrangement was contrived and made which placed each moon, as it came under observation, in absolutely the same position as its predecessors with respect to the focal axis of the lenses of the lantern and the beam of light; but to ensure no possibility of movement passing undetected, the shutters of the occulting eyepiece were arranged that each moon should occupy the same position in the field, and the readings of the vernier proved that no movement of the tube had taken place unnoticed. With the arrangements completed, the appearances of the little moons in the wedge were studied on several occasions, for it must be remarked that they were found to be very different from those afforded by the examination of points of light such as is given by the real satellites, or by the stars; upon which nearly three months had been previously spent in acquiring familiarity with the instrument. This point has a special bearing, as will be seen hereafter.

Before making the final comparisons the apparatus was rearranged in such a manner that at every three or five observations a fresh extinction should be made of the white moon, in case any waning or irregularity of the light should have unknowingly occurred in the interval. This plan (although it was found afterwards not to have been necessary, the lamp having burnt so steadily) was carried out through the final determinations, the mean of over sixty extinctions being tabulated as follows:—
White with grey:

1	2	3	4	5	6
33	·58	·16	·58	·42	·05

White with black,

33	2·21	·12	·13	·87	·01

In the first column is shown the number of wedge extinctions; in the second the difference of magnitude; in the third the average deviation in magnitude from the mean of the observations themselves; in the fourth the resulting albedo of the two moons; in the fifth the deficiency of the albedo; in the sixth or last the difference of albedo produced by an error of ·1 magnitude.

This concluded the first series of experiments, which sufficiently established the following fact. When small discs of equal areas but of different albedo are placed upon a larger one

(the larger and smaller discs bearing in size the relation approximately of *Jupiter* to his satellites) they assume certain tints of shading, which directly depend upon their deficiencies of albedo, as compared with that of the background. Moreover, it further shows what difference of magnitude, and consequently what approximate difference in albedo, is necessary to produce appearances similar to the grey and black tints that the first, third, and fourth satellites have assumed during transit, an albedo of ·58 being necessary in the first instance, and ·13 in the second.

Series 2 was carried out with a somewhat different view, viz. to ascertain what effect on the general appearances was caused by the employment of backgrounds of the same reflective power but of different size. Accordingly all sizes were tried, from a foot in diameter down to a tiny disc exceeding the little moon by only one diameter; and, strange as it may seem, the contrast became the more impressive the smaller the background employed so long as it exceeded the smaller moon by about two diameters. It was also noticed with all sizes of backgrounds that when a moon of equal albedo was placed upon them it became invisible. Another peculiarity was also witnessed, that with small backgrounds, say of three or four times the diameter of the moon, although the same number of coatings of ink was required on the moon to make it appear black as its shadow, one coating less sufficed to make it commence to turn grey. When the background was reduced to less than two diameters the black or grey appearances were scarcely recognisable, and only a faint waning of the light was noticeable.

This set of experiments shows that the darkened tint of a disc when superimposed on another and larger one, be its size whatsoever, is due to the difference of albedo between the discs compared, and has little or no relation to the total quantity of light reflected by either. As the discs approach one another in size (so long as the greater exceeds the less by about two diameters) slightly less difference in albedo than ·42 will cause the smaller to appear grey, but a difference of ·87 is still required to make the dark moon (technically so called) appear as black as its shadow when superimposed on the larger disc.*

Series 3.—These experiments were instituted for the purpose of ascertaining the effect produced on a small disc by the approach of another and larger one as seen in a telescope.

The first experiment tried was that of moving the three-inch pure white disc towards the dark moon (technically so called), which it will be remembered was found to have an

* It is important to add that in making this statement it is absolutely necessary to have a shadow wherewith to make the comparison. We often through these experiments thought a moon worthy of such definition when in reality, on comparing with a shadow, it was found to be nothing of the sort. This doubtless accounts in a measure for the various terms employed by different observers for the tintings of the satellites during transit, for often there is no shadow wherewith to make comparison.

albedo of ·13 as compared with the larger one, both being strongly illuminated. As the larger one was advanced towards the smaller, it was distinctly noted that the latter steadily appeared to become less and less brilliant, until, when the two were nearly in contact, it was exceedingly faint and tinted looking. It will be seen hereafter a distinction will have to be drawn between the immediate effects due to the approximation of a large disc to a smaller one, and the immediate presence of a sphere with the same little moon; effects due to the loss of light at the edges and limb of a sphere in comparison with the uniform amount reflected by a disc.

The same experiments were repeated with moons of all values of albedo, from unity to that of 13, and although no definite figures can or could be actually given or arrived at, still it was evidently true that the amount of apparent loss of brilliancy depended upon the difference in albedo of the moon and the advancing disc. With a pure white moon there seemed no waning of brilliancy, but as the difference of albedo increased, so the effects of loss in brilliancy, tinting in fact, became the more apparent. The same experiments were repeated with backgrounds of all sizes, having the same reflective capacity; but so long as they were twice the diameter of the little moons the above description holds good. When, however, the advancing disc was reduced to the diminutive size of about two diameters, or less, the effect was but slightly noticeable.

The result then of these experiments, contained in this the third series, shows that if two discs (whose proportions are such that one exceeds the other by at least two diameters) are made to approach one another,* any apparent loss of brilliancy in the smaller is directly in accordance with the difference in albedo between it and the greater, and has no relation to any difference in the relative quantities of light reflected by either. Discs of equal albedo do not affect one another, and no well-marked effect seems noticeable until the difference of albedo between the discs exceeds ·42. Small discs only slightly affect others which are smaller still provided their diameters are sensibly equal.

Series 4 was undertaken for the purposes of witnessing the effects produced by placing the little moons in front of a sphere.

A $3\frac{3}{4}$-inch sphere of plaster-of-Paris was made and illuminated brilliantly. As in the previous series of experiments one observer had charge of the moons and the other of the telescope. The phenomena were witnessed at a distance of about sixty yards through the Tulley telescope by both observers, and noted.

It was found that the moons with the same albedo appeared black and grey as before, but, what was far more surprising, that

* The larger was advanced towards the smaller in preference to the opposite course, because it was found that shifting the smaller whilst examining it caused a disturbing effect on the mind. The results, however, would not be in the least affected.

all the phenomena of the dark transit could be completely reproduced. I have witnessed the real phenomena very repeatedly, but I did not contemplate a reproduction from the employment of such simple means.

Whilst the dark moon having an albedo of ·13 was advancing towards the artificial planet its light became fainter and fainter, but still of sufficient brilliancy to remain a bright spot when on the limb. Still continuing its journey across the artificial planet, and having arrived at an angle of about 65° measured from the centre,* it became lost to sight, reappearing on arriving at an angle of about 55° to 60° as a dark spot, which in a short time occupied in further progress became as black as its shadow. The effect was not a little surprising, seeing that it was totally unexpected. No changes in the phenomena were visible when the same experiment was repeated at different (so called) parallels of latitude in the plaster cast.

It became evident from the results of the previous experiments that these phenomena were due to progressive differences of albedo between parts of the sphere and the little moon which took place as the transit progressed; and as it was equally apparent that such changes could not have taken place in the albedo of the satellite, it was shown to be due to increase of brilliancy of the background. It was then determined to photometrically measure the differences in the amount of light reflected from the edges and limb, as compared to that reflected from the centre (technically defined) of a sphere; which differences are described in the following series.

Series 5.—The sphere was first examined with the occulting eyepiece, and the loss of light that was then plainly visible when the limb was compared separately and *immediately* with the centre (technically so defined) was felt to be far more than would otherwise have been anticipated. The contrast was a striking one. All kinds of means were devised to measure this loss photometrically, but after several attempts it was feared such could not be done with accuracy owing to the difficulty of preventing a portion of that already wedged being photometrised again unconsciously. Then also it was felt that actual points at definite angles were what was really required to be wedged, which of course with the present means was impossible. Ultimately the quadrant examined was divided and marked into ten perspective squares, each of which exactly fitted a similar one in the occulting eyepiece; and with this method, rude as it was, the following figures were obtained. They are not, however, so trustworthy as those subsequently obtained and described further on, which I believe to be as accurate as possible:—

* These angles are counted thus: "Contrality" is a term used in a technical sense, by which is meant a line joining the axis of the telescope to the true centre of the sphere: angles are counted from this zero to 90°, which is called the limb.

1	2	3	4
29°	·31	·75	·07
34	·36	·72	·07
39	·68	·53	·04
49	·87	·45	·06
56	1·40	·28	·06
78	2·56	·09	·07

In the first column is given the nearest approach to the mean angle of the perspective figure; in the second, the difference of light between the centre, or rather the district situated about it, and that angle, the less in light being expressed in magnitude; in the third, the resulting albedo; and in the last the average deviation from the mean of the observations in magnitude.

Series 5*a*.—The object of this series was to detect and measure as accurately as possible, and by a different arrangement, the loss of light reflected from the limb and edges of an unpolished sphere, as compared with that reflected from the centre (technically so called) by employing a card placed at different angles to the incident light. The following arrangements were designed and made. A white card was held by an apparatus truly vertical and at right angles to the axis of the observing telescope, the light being thrown upon it from a reflector concealed from view. The rays proceeding from the reflector were arranged to be in the same vertical plane as the telescope, and the small loss which occurred from their impinging on the card with a trifling inclination or obliquity from below upwards was felt to be of no consequence, as it equally affected all positions of the card, and especially as it was not the total reflective capacity of the card that was being measured, but merely the difference in the amount of light reflected to the observer when the card was turned through different angles; for such were accurately known, the base of the instrument being provided with a graduated circle.

The mean of several observations is shown in the accompanying table:—

1	2	3	4	5
30°	·34	·01	·735	·265
40	·75	·02	·500	·500
50	1·09	·07	·367	·633
60	1·23	·04	·323	·677
65	1·46	·07	·261	·739
70	1·91	·04	·172	·828
75	2·19	·04	·133	·867
80	2·74	·04	·080	·920
83	3·27	·03	·049	·951
86 30′	3·87	·05	·027	·973

Column 1 gives the exact angle of observation; column 2 the loss in magnitude; column 3 the average deviation from the mean of the observations in magnitude; column 4 the resulting albedo; column 5 the loss of albedo at the same angle.

It will be seen from this table, as was foreshadowed in the previous one, that from centrality, as technically defined, to an angle of about 30°, there is practically no loss of reflected light, anyhow to a measurable amount, in the wedge photometer; but that from this angle to the limb the loss is by small increments at first, but after a little by rapidly increasing ones. The loss when reduced to *light* approaches very approximately the tangent of the angle.

This table brings prominently before notice when viewing a sphere as a whole—a mere disc in the telescope—that unconsciously all grades of albedo are blended simultaneously in the light that is reflected on to the retina. Owing to this being so different from the uniform albedo of a disc, it was thought desirable, if not actually imperative, to conduct even yet a further series of experiments to ascertain whether any different effects were produced from this cause upon a moon in transit; in other words, whether the results of the previous experiments and their facts and figures might not require modification when a background composed of such a combination of albedos was under consideration.

Series 6 was conducted for this purpose. The apparatus employed was a hemispherical sphere, a hollow-like shell, three and three-quarters of an inch in diameter, of plaster-of-Paris, supported by a hollow frame of papier-mâché, in its turn resting on a similar support of very thin wood, so arranged that different concentric rings could be removed at will, leaving the others undisturbed. The apparatus served its purpose admirably. The first movable portion was the centre zone (called in the future the "zone of equity," or "unity centre," from the fact that with the wedge it will be remembered no difference in the light reflected was perceptible from the centre to its edges), which extended from centrality, as technically defined, to a distance about 30° on each side. The second ring reached from 30° to 60°, the third from thence to an angle about 70°, whilst the portion remaining, really attached to the apparatus itself, consisted of but little else than the limb of the artificial planet. The illuminating arrangements and telescope employed were the same as before, the artificial planet being placed at a distance of about sixty yards. The moon selected was that having an albedo of ·13, and the following experiments as to the effects produced upon it by removal of one or more of the various zones were conducted:

A. Moon advanced towards the artificial planet with unity centre *in situ*, and with it removed. No apparent change in the appearance of little moon.

B. Moon placed on limb. No apparent change in appearance of little moon, whether unity centre *in situ* or removed.

C. Moon placed on zone about angle of 65° to 70°, where it usually exhibits the phenomenon of disappearance. No apparent change with centre, present or absent.

D. Moon left in same position and second zone removed. No apparent change, whether second zone was present or absent.

E. Moon placed on portion corresponding to about the angle of 60°. Little moon appeared *exceedingly black* when unity centre (which extended only to 30°, it will be remembered) was present, but recovered most of its brilliancy, appearing rather more tinted than usual when it was removed.

F. Moon untouched; second zone removed as well as centre. Moon recovered its original brilliancy.

The experiments, like all of the previous, were repeated with another observer at the telescope, and the results compared; but, as in the previous series with discs, it was found that no personal or subjective influence interfered with the power of repetition.

This concluded the sixth series of experiments, the summary of which may be advantageously considered with those of the whole, for I submit it will be seen by their careful consideration that much light has been thrown upon, if not a complete explanation afforded for, the apparently peculiar behaviour of all the satellites of *Jupiter* during transit, that is, provided the albedos of the four moons, as ascertained by the wedge photometer, are found to be numerically in accordance with those figures ascertained by these experiments to be requisite.

It must be first restated that for a small body or disc to appear as black as its shadow when superimposed on another (with certain limitations as to their respective sizes), there must be a difference of albedo approximately amounting to ·87, and a difference of about ·4 for it to appear grey (Series 1). Then it must be further borne in mind that it has been experimentally and photometrically proved that an unpolished sphere reflects less light at its limb and outer zones to that reflected at its centre one; that centre one extending, so far as the appreciation of the eye is concerned, from absolute centrality (technically defined) to an angle of 30°. If then a moon with a relative albedo of about ·13, say for convenience ·2, be advanced towards and upon a planetary sphere, the following effects are exhibited. As it approaches the limb the moon wanes in light, owing to the fact (Series 3) that it is advancing towards an object of superior albedo. *

* The fourth satellite having the smallest albedo, as will be hereafter seen, is the reason why it appears fainter on nearing transit than any of the others.

Proceeding on to the limb, it is found to be bright for a short duration—in other words, remains apparently illuminated, because the albedo of the limb is not of sufficient magnitude to give a difference of ·87, that required to make the smaller disc turn black, or even to permit of the small difference of ·4, the quantity which has been found necessary to make it change to grey. As it approaches to about an angle of 65° to 70°, the hitherto puzzling phenomenon of disappearance is exhibited; but this is now explicable by the consideration that such takes place when the moon is over part of the sphere, where its albedo and that of the satellite are approximately equal, and hence according to Series 2 no other effect could be expected.

Once past this position, and having arrived at an angle of about 55° to 60°, it will be remembered the moon suddenly turns dark, becoming rapidly as black as its shadow. Two causes are found to bring about this effect. They are: first, the simple fact that the moon is advancing towards a surface, the neighbouring zone of 50° to 60° possessing a superior albedo, and hence, according to Series 3, its brilliancy is diminished; secondly—and this is not the less remarkable, inasmuch as it accounts for the greater amount of tinting—because the central zone, under the circumstances peculiar to the situation, possesses such a power of affecting the eye that, although at some distance from the moon (which is still supposed to be at about the angle of 60°), it really acts more as if it *were itself* the background; and being so rich in albedo at once is of more than sufficient power to make the moon assume its blackened aspect. Thus, then, will it now be understood why this sudden and increasing darkness steals so rapidly over the satellite, because these two causes mentioned act *simultaneously* and *conjointly* upon it. This singular peculiarity — not noted previously with discs because of their uniformity in albedo—was detected and proved in the last or foregoing series by the simple process of removing the various zones in question, with the effects already noted; a proof in itself, I submit, of a crucial character.

Finally, and scarcely need it be added, the phenomena displayed by the other satellites are easily understood after what has been written. The second satellite is always white during its superior conjunction, because its albedo will be found to be so characteristically high, as rich almost as the background itself; that of the first satellite will likewise be found sufficiently so under most circumstances to enable it to maintain some superiority in colour over the background when in transit; that is to say, will usually present some shade of grey instead of jet-black when superimposed upon its primary. But as to the third, which seems to enjoy a certain amount of variability during transit, that satellite probably presents as its rotates on its axis sides of differing albedo; one of just sufficient intensity to enable it to maintain an aspect of whiteness; and the other, and greater part, with so much weaker an albedo—perhaps from

the presence of spots—as to enforce it to assume one of the varied tints of grey, or even to turn black, as Maraldi saw it in 1707.

In conclusion, with respect to any unique, rare, or other unusual phenomena presented by the satellites during transit, or even during their elliptic journeyings around their primary, it remains but to be pointed out that such can be easily conceived to arise from some of the effects of contrast belonging to one or other of the series of experiments before described; and this remark especially applies to the fourth satellite simply because, owing to its weak albedo, as will be shown hereafter, it is the moon most readily affected; and also in a measure this remark applies to the very different albedo which neighbouring portions of *Jupiter's* disc do themselves present, and which would give rise to modifications in "background" effects.

Obtaining the Relative Albedos of the Satellites with the Pritchard's Photometer.

The method employed to obtain the albedos of the satellites was as follows. Wedge-readings were taken of the different satellites on as many nights as possible during the year with the 6·5-inch Alvan Clark refractor, *Jupiter* being extinguished with the aperture reduced to one-eighth its linear diameter.

After the first few sets of observations had been secured, and the resulting albedos computed in the manner hereafter described, some doubts were thrown upon the accuracy of the results, notwithstanding their agreement *inter se*, on account of their differing so largely with those obtained at Harvard with the polarising photometer. As it seemed possible that an error might be found in the fact that the magnitude of *Jupiter* had been estimated up to this date, partly by observation and partly by calculation, based on the theory of apertures; and as the residuals of the observations themselves appeared satisfactory—being indeed less than those of the Harvard observations—the theoretical addition for the reduction of aperture became the subject of inquiry. If the law that the intensity of the light of a star as received in the focus of the telescope varies as the square of the linear aperture, the reduction of area in this case would entail the addition of 4·5 magnitude—the quantity actually employed—to that observationally obtained from the extinctions with the reduced apertures. But as the resulting albedos of the satellites did not present that accordance with those obtained by Professor Pickering, and inasmuch as the magnitudes representing the extinctions of *Jupiter* were manifestly too high, leaving a difference between them and the satellites that was evidently too small, it was felt (seeing the actual observations themselves were not apparently at fault) that the law in question was not applicable to the telescope employed. On referring to the literature of the subject, it was acknowledged not to comply with the required accuracy, and indeed Professor Pritchard, who had given the matter some consideration in his memoir on the wedge photometer, had

related that such law was not to be held in anything but in a general sense, as so much depended on surrounding circumstances.*

It became necessary then to inquire what was the correct magnitude to be added to the observations, to compensate for the loss of light caused by the reduction of aperture. It was ascertained in the following manner at the suggestion of Mr. Plummer, of Oxford University Observatory, whose experience with the wedge photometer is so considerable.

A star was to be selected of such magnitude as to enable the photometer to extinguish its light at the thick end of the wedge with the full aperture, and at its thin end with the aperture reduced to one-eighth its linear extent. By this simple but ingenious means it will be seen the interval of the wedge itself between the extinctions corresponds to the loss of light by the reduction of aperture, and this too without the adoption of any theoretical law or computation whatever. Two stars were selected, *Polaris* and δ *Leonis*.

The following table gives the actual extinctions :—†

Polaris.		*δ Leonis.*	
Full Aperture.	One-eighth.	Full Aperture.	One-eighth.
8·06	1·47	7·26	0·61
7·80	1·18	7·80	0·49
8·24	1·18	7·63	0·53
8·10	1·03	7·60	0·62
7·91	1·17	7·38	0·65
7·82	0·94	...	...
8·04	0·98	...	...
8·01	0.95	...	...
8·17	1·11	...	...
8·23	1·09	...	...
Mean 8·038	Mean 1·100	Mean 7·534	Mean 0·580
Difference 6·938		Difference 6·954	
In Mag. 4·93		In Mag. 4·95	

With Polaris 4·93
With δ Leonis 4·95
Adopted Mean 4·94 Mag.

The adopted mean then hereafter used was 4·94 magnitude: this

* *Memoirs of the Royal Astronomical Society*, vol. xlvii. pp. 387–391.

† In comparing the errors in the extinctions by the Clapham wedge with those of the Oxford, it must be remembered the former is divided into half-inches, the latter into inches. Errors in the former must therefore be divided by two to render such comparison exact.

was added to the extinctions of *Jupiter* with the reduced aperture instead of that obtained theoretically (which was 4·5 magnitude) being an addition of ·44 magnitude.

As many observations of the satellites were taken as the weather permitted, and the number of nights happened to be the same as utilised by Professor Pickering; but that observer on a few nights duplicated his observations, hence numerically they exceed those used in this case. The method of reducing the observations, somewhat operose, need not be here detailed, for it will be found fully described in a most comprehensive manner on pages 245 and 246 of the *Annals of the Harvard College Observatory*, vol. xi. 1878–79.

The whole of the observations being secured and reduced, it was found unexpectedly that they were again affected by some systematic error, for the resulting albedos of the satellites in two instances exceeded that of *Jupiter* itself, disregarding for the moment their utter discordance with those obtained at Harvard. No error in the computations being discoverable, after some loss of time it was determined to ascertain if the error had occurred from the fact that with these observations estimations of *points of light* as represented by the real satellites had been compared with extinctions of *Jupiter*—an object of *sensible area*. Previous experience showed, as it has been pointed out, that some time had to be expended in acquiring the experience necessary with both classes of extinctions, for indeed with each the photometer appeared as a new instrument; and it was conjectured as possible that although comparing extinctions of points with points, or areas with areas, gave correct and reliable results, that perhaps when the one class of observations were compared with the other, systematic errors might be introduced which would vitiate the conclusions.

To devise a means of ascertaining this point was very difficult, but it was contrived in the following manner through the kind suggestion of Captain Abney.

Two holes were to be made—one as small as possible, to represent a point of light, and another of far larger dimensions. They were to be placed at as great a distance as possible from the observing telescope and illuminated. The difference obtained photometrically was to be compared with that obtained theoretically from a careful measurement of the holes with a micrometer. Two such holes were ultimately made and measured, one being $\frac{21}{10000}$ths of an inch and the other $\frac{33}{500}$ths of an inch diameter; or approximately the relations of *Jupiter* to his satellite, viz. about 33 to 1. The amount of light issuing through them was ascertained photometrically and measured theoretically. The same process of reducing the aperture was resorted to for extinguishing the light of the larger hole, and the same plan adopted (as before explained) for ascertaining the amount of light lost in using the diaphragm. The experience derived from previous experiments was carefully utilised (as to using the very same beam of light, its waning, &c.),

and an especially constructed arrangement was made to place each hole in exactly the same position as occupied by its predecessor with respect to the lenses and the axis of the observing telescope.

The following figures were obtained:—

1. **As ascertained by wedge:**

Amount of light in mag. passing through great hole ...	3·09
Amount to be added equivalent to that cut off by diaphragm	4·66
Total amount in mag. of great hole	7·75
Total amount in mag. of small hole	0·99
Resulting difference in mag.	6·76

2. **As calculated theoretically,** assuming one hole was 33 times the linear diameter of the other ... ... 7·59 mag.

Thereby showing that with the photometer there is a loss amounting to ·83 magnitude when a point of light is photometrically compared with an object of sensible area.

It was evident then that this systematic error was to be added to all the extinctions of *Jupiter*, and this is what has been done in the table that follows:—

1	2	3	4	5	6
I.	8·12	·656	8·13	·652	1″·081
II.	8·40	·715	8·27	·809	″·910
III.	7·88	·405	7·76	·453	1″·537
IV.	8·73	·266	8·89	·230	1″·282

In column 1 is shown the number of the satellite; in column 2 its difference in magnitude with that of *Jupiter* as obtained by these observations; in column 3 the resulting albedo; in column 4 the difference in magnitude between it and *Jupiter* as obtained by Professor Pickering; in column 5 his resulting albedo; and in column 6 the measured diameter of the satellite adopted by both observers.

These results, seeing they are obtained by instruments of entirely different character, are very reasonably in accord, but it must be borne in mind a slight modification would be entailed in each if the adopted diameters of the satellites were changed; and some discrepancy exists between observers on this point, their measurement being no easy matter.

Taking then for granted these figures approximately represent the relative reflective powers of the satellites as compared with *Jupiter*, it only remains to be said that their several relations are reasonably in accord with the requirements set forth in the contrast experiments of the previous sections, as necessary to exist to establish phenomena such as are exhibited by the real satellites during transit.

Reducing the whole subject to a short conclusion—which has involved no less than four years of work, as consecutive as the continually interruptive nature of the profession to which I belong has allowed, and the labour too of carrying out upwards of two thousand extinctions in one form or another—is this, that the perpetual whiteness of the second satellite, and the darkened tints of the others during transit (not to say in explanation of the casual appearances strange and unusual reported at other times) is due to differences in their relative albedo as compared with that of *Jupiter*, and is not dependent upon the relative quantity of light reflected by one or the other, or upon any physical peculiarities of the Jovian system.

In conclusion, I must once more be allowed to record my thanks to my friend Mr. Plummer for placing his many experiences so liberally at my disposal, and in addition for his having overlooked all the albedo computations; and also to my friend, the Rev. James Holroyde, who has kindly verified by far the majority of the contrast experiments.

Ivy House, Clapham Common, London, S.W.

The Total Solar Eclipse of 1887, *August* 19.

By Dr. Ralph Copeland.

Professor Bredichin, of Moscow, finding that the central line of the total eclipse of the sun on August 19 passed almost exactly over his country seat of Pogoste, near Kineshma, most hospitably invited the Council to nominate two members of our Society to become his guests for the purpose of observing the eclipse. The Rev. S. J. Perry was chosen as one representative of the Society, and the writer takes this opportunity of thanking the Council most heartily for having selected him as the other fortunate candidate. Thanks to the efforts of distinguished Russian *savants* and the representations of the British Foreign Office, every facility for the introduction of eclipse apparatus into Russia was afforded by the Minister of Finance at St. Petersburg.

Although the weather on the important morning was so unfavourable that no records of any scientific value were secured with the apparatus sent from Dun Echt Observatory, it may not be out of place to give a short account of the preparations that were made, and of the circumstances attending the eclipse itself.

Photographic methods seeming to offer the greatest facilities for securing unequivocal records, both of the forms and spectra of the solar appendages, it was resolved to dispense altogether with eye observations. The photographic apparatus consisted of the following parts, which were all carried by a massive equatorial mounting.

A 6-inch telescope of about six feet focal length, with a dense flint glass prism of about 12° angle in front of the object-glass formed an open spectroscope. This was for photographing the chromosphere as a series of more or less separated rings of different degrees of refrangibility. It would also have given sharp narrow spectra of any specially brilliant points in the prominences or chromosphere.

Riding on this telescope was a star spectroscope with a 2-inch object-glass to form an image on the slit. This combination was directed so as to point some minutes of arc clear of the Sun's limb, when his image was central in the other instruments, with a view to photographing the spectrum of the corona.

Secured to the long free end of the declination axis was a camera of four inches aperture and thirty-two inches focus. This camera is the one which was so successfully used for Lord Crawford, in India, by Mr. Davis in 1871, and by using it for short and very short exposures, it was hoped that it might again give good photographs of the corona and prominences.

Partly balancing the preceding instrument with regard to the declination axis was a landscape camera, fitted with a spool of Eastman negative paper, for securing such views of the corona as could be obtained with about one minute's exposure.

Clamped on the long-focus instrument was yet another camera of large aperture with a 5-inch × 4-inch plate. This was to have been exposed for nearly the whole time of totality to determine the extreme photographic extent of the corona. After some trials it was arranged that the cameras at the tail end of the declination axis should be worked by James Macpherson, the attendant from Dun Echt Observatory, whom Lord Crawford had very considerately sent with the party, while I looked after the pair on the declination side. Two of Professor Bredichin's pupils kindly undertook to note down the time for us.

To simplify the working of so many cameras one set of slides fitted both the 6-inch telescope and the 4-inch camera, while another set were common to the small camera and the star spectroscope. The mounting having been originally designed by Messrs. T. Cooke & Sons for an 8-inch telescope was not at all overloaded with this apparatus. Several features in this mounting afford such great facilities in setting up the instrument that they well deserve mention as specially desirable in stands designed for eclipse expeditions. They are:—Power of turning the whole head of the stand right round in azimuth and clamping and adjusting it in any position. The outside of the polar axis cradle is parallel to that axis, which can therefore be inclined at the proper angle under the guidance of a spirit-level and angle-gauge. The declination axis is provided with a spirit-level.

The detached bath-house at Pogoste having been placed altogether at our disposal was easily turned into so convenient a

dark-room that the necessary trials of plates were made with every comfort. A reflecting circle belonging to Professor Bredichin provided the time with all desirable accuracy for the work contemplated.

As the object-glass prism deflected the light about 8°, the 6-inch telescope had to be directed to a point at that distance from the Sun. By turning the refracting edge of the prism round the optical axis of the telescope this deviation can be made to take effect in any direction, but the most convenient direction is either along an hour circle or to a point in the same parallel as the object under observation. The latter position was chosen as being more likely to throw the spectra of the prominences clear of each other in photographs taken near the beginning and end of totality.* It also simplified the attachments for the small spectroscope and the cameras.

For some time before our arrival at Pogoste, on August 4, the weather had been very fine, but a heavy thunder-shower on the afternoon of the next day was the beginning of a complete change in the weather. For, although it was repeatedly clear just at sunrise, it was very seldom that uninterrupted views of the sun or stars could be obtained. At 5 A.M. on the morning to which we had all been looking forward for so many months, the sky was almost altogether overcast, but about the time of first contact the clouds separated so that the Sun shone brightly. But when about half the Sun was eclipsed the drifting clouds began again to thicken so quickly that some twenty-five minutes before the total phase the Sun was completely obscured. The daylight now began to lessen rapidly; this, together with the swiftly moving cloud-drift, indicative of a strong wind overhead, closely resembled the gathering of a thunderstorm. So close was this resemblance that it required some effort to bear in mind that the darkness was mainly due to the progress of the eclipse, and that in spite of the fading light the clouds might possibly be clearing away. As will be seen, this is exactly what happened, but the favourable change unfortunately came a few minutes too late. Not knowing how dark it might become, a couple of candles were kept burning on a table some ten feet behind the instrument. When the chronometer showed that totality had already commenced, I noticed that the candles cast a distinct shadow of the observer on the instrument. At the same time the sky gave so much light as to remove all fear of being inconvenienced by the obscurity. The candles were therefore blown out. The precious moments of darkness slipped away, until just at the very last instant of totality the eclipsed Sun, surrounded by a brilliant ring of corona, burst out through a small opening in the clouds. Apparently at the very same moment the light of the Sun broke forth. Every effort was made to

* Something might be gained in this respect by making the deflection take effect in the plane of the Moon's orbit.

obtain photographs, and it was not until the negatives were developed that all hope of having secured some traces of the corona and prominences were given up. As might be expected, the spectroscopic negatives of the narrow solar crescent show some of the chief lines of the spectrum, H and H_1 being easily recognised. The star-spectroscope, too, yielded a very fair spectrum, but it is merely that of daylight. Many negatives of partial phase were taken, but they only serve to show that the plates were in good order.

One circumstance may be mentioned as showing how near we were to one of the few spots where the eclipse was well seen. During totality I had noticed that the sky near the S.S.E. horizon, which was visible from my post, was quite clear, and tinged as if the sun were setting. A few days afterwards we learnt from the captain of the Volga steamer *Alaska*, which was then between Kineshma and Nischni Novgorod, that he had seen the whole of the total phase unimpeded by clouds. His position would about agree with the clear gap visible from Pogoste.

I cannot conclude without expressing my warmest thanks to Professor Bredichin for the hearty welcome which he and his whole family accorded to us in Russia.

Dun Echt Observatory :
1887, *November* 9.

The Total Solar Eclipse of August 19, 1887. By the Rev. S. J. Perry, F.R.S.

Although the clouds interfered most seriously with the observation of the solar eclipse on August 19, I feel it to be my duty, as a delegate of the Council, to lay before the Society a brief report of the manner in which their mission was carried out; and I trust that some at least of the details I am about to mention may not be found useless for future eclipse observers. Most of the Fellows will remember that our associate Professor Bredichin sent a very generous invitation to the Society, offering hospitality to any two of its members who might wish to observe the total eclipse; and that Dr. Copeland and myself had the honour of being nominated by the Council as the representatives of the Society.

The Astronomer Royal most kindly placed at my disposal the coronagraph and photo-spectroscopes used by Mr. Maunder in 1886; so I resolved at once to devote my whole attention to the photographic portion of our work. A full description of the instrument will be unnecessary. It will suffice to mention that two spectroscopes, with cameras attached, were fastened to the square tube of the coronagraph, and the same tube carried a

4-inch achromatic and two small finders, one of which gave a projected image of any bright object that might be in the field of view of the telescope. I removed the 4-inch telescope, which I did not think I could use advantageously, and replaced it by a second coronagraph of somewhat shorter focus than the first. The two small finders were exceedingly useful, as one served for fixing accurately the position of the instrument, and the other for retaining the Sun in the centre of the field. The coronagraph, which is the joint property of the Royal Observatory and of the Royal Society, is most unfortunately very incomplete, and much time was necessarily lost in correspondence before all the essential parts could be got together. Besides the Royal Society and the Astronomer Royal, I have to thank General Festing and Captain Abney for the loan of a most valuable 4½-inch photo lens with camera and dark slides; Mr. Hilger for a 5-inch object-glass; Mr. Lockyer for a 2-inch photo lens; and Dr. Schuster for the tube of the second coronagraph. Having collected the parts I erected the instrument at Stonyhurst, strengthened the tripod stand, adapted it to the required latitude, and so arranged the two-prism spectroscope that a comparison spectrum might be taken on the same plate as the coronal lines. Mr. Maunder very kindly secured the same advantage for the one-prism spectroscope by a different arrangement; I shifted the camera and exposed different parts of the same plate, whilst he covered different parts of the slit. Experiments were then made with sensitised plates from different makers: the Ilford, Derby, Eclipse, and Isochromatic were those used. All gave good results. The Ilford plate I found most reliable for long exposures, and the Isochromatic was perhaps slightly more satisfactory for spectrum photography; but as I wished to make the photographic arrangements as simple as possible, I thought the Derby plate would suit me better altogether than any other. I therefore ordered a special set of quarter-plates to be prepared for the eclipse, the emulsion being identical with that used for the Greenwich dry plates, and I told the maker to back them carefully and to pack them in special boxes. Two dozen of these plates were cut into halves by my assistant for use in the spectrum cameras. With a narrow slit, and an exposure of one second, excellent spectra were obtained from clouds near the Sun, and an exposure as instantaneous as possible gave similar results with direct sunlight. The lunar spectrum required about two minutes for a strong picture, whilst the Moon itself was well photographed in half a second. Beach's developer was found to answer well for all purposes, and was carried already mixed in bottles, two bottles of each ingredient being taken in case of accident.

The instruments and chemicals were sent by steamer from Hull to St. Petersburg, Messrs. Wilson & Co. taking the greatest care in seeing them well stowed on board, and a letter from the Russian minister freeing them from all duty, and even

from examination on arrival at their destination. This letter was due in great measure to the forethought of Professor Struve, who took the greatest pains to smooth the way for the eclipse observers, and gave us a most hearty reception at his magnificent observatory at Pulkowa. Every assistance was rendered to us at St. Petersburg by Mr. Saunderson, and he also telegraphed to the directors of the Steamboat Company on the Volga to secure all facilities during our journey to Pogost. I have also to acknowledge the kindest attention from Sir R. Morier, British Ambassador at St. Petersburg, and from other members of the Embassy.

At Kineshma we were met by Professor Bredichin, who more than fulfilled the high expectations we had formed from the kindness already shown us in Russia. Pogost was placed entirely at our disposal, every comfort was supplied, and we enjoyed the precious advantage of being left entirely free to attend to our preparations, any number of workmen being near at hand to assist when needed. A fortnight was spent in mounting instruments, testing chemicals, and making final adjustments and arrangements. A very few things were damaged by the journey, and the watchmaker of Kineshma easily repaired the mischief. A Russian bath-house served excellently as a photographic hut, and we were well supplied with rain and spring water for washing our plates during the process of development. A large ice-house also formed part of the establishment, and would have been more useful had the temperature remained at the height we found it on arrival. Most fortunately we were joined a few days before the eclipse by Miss Brown, of the Liverpool Astronomical Society, and her cousin Miss Jeffreys, and the latter most obligingly and most efficiently took charge of the cameras of my spectroscopes during totality, thus leaving me entirely free to attend to the two coronagraphs. With the one-prism spectroscope I hoped to obtain on the same plate a spectrum of the corona and two solar spectra for comparison, and with the two-prism spectroscope I though I might secure two spectra of the corona, one with, and the other without, a comparison spectrum on the same plate. I found by rehearsals that by giving undivided attention to the coronagraphs I could with a clear sky obtain easily during the $2^m\ 10^s$ of totality twelve photographs of the corona with the following exposures: four of 1^s, two of 2^s, two of 5^s, and one each of 20^s, 40^s, and 55^s. I was also prepared to expose plates in each instrument, so that the position of the Sun's axis might be determined by two pictures of the solar crescent on the same plate. For the same object two pointers were photographed on each negative.

The morning of the 19th, like most of the mornings that immediately preceded it, was cloudy, but the clouds were broken, and we thus obtained occasional glimpses of the solar crescent before totality, during one of which I exposed a plate; but clouds prevented a second picture being obtained on the same plate.

Seeing the nature of the sky I was forced at the last moment to alter my previous plan, and I resolved on trying only the short exposures of 1^s, 2^s, and 5^s. But even in this I was again disappointed, for during totality there was not even a partial break in the clouds, except at the last moment, and then I exposed a plate with as little delay as possible, but a minute arc of the photosphere had already appeared in the heavens. Had I exposed this plate for a somewhat longer time I might have obtained a slight trace of the corona, but it could scarcely have been of any practical utility. The negative shows a less bright extension of the photospheric arc, which must, I think, be due to a prominence of the chromosphere. Several pictures were taken whilst the solar crescent was still very narrow, and the diffused light is much stronger and more extended on the convex than on the concave side of the crescent, but this probably is due to the imperfect sky combined with the greater intensity of the convex arc rather than to any appearance of inner corona. In the second negative one of the cusps is decidedly sharp and the other blunt, and there is a marked difference in this respect in the successive pictures; but as the crescent became wider all bluntness disappeared. During totality the darkness was not great, the clouds possibly diminishing the effect. At any time I could have read the face of a watch without much difficulty, but lamps were ready in case of need.

The disappointment at so meagre a result would in any case have been great, but we felt it more intensely as we saw what distress it caused the hospitable family, who had done so much to ensure our perfect success. Personally I have to acknowledge my great obligations, not only to Professor Bredichin and his family, but also to Dr. Copeland and Mr. Macpherson for their generous aid during the time of preparation.

Observations of Comets made at the Orwell Park Observatory in the years 1886–87. By John I. Plummer, M.A.

Comet VII. 1886 . . . (*Finlay.*)

1886.	Greenwich Mean Time.	Comet—Star. Δα	Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Nov. 18	6 21 28	+0 52·04	+ 7 36·1	6–6	20 10 47·49	9·3155	−22 41 20·5	0·9137	+1·72	+11·9	1
24	6 32 58	+1 46·26	− 2 13·4	7–7	20 39 35·13	9·3289	−20 49 17·2	0·9092	+1·74	+12·8	2
29	6 25 24	+1 11·30	− 3 2·6	8–8	21 4 17·81	9·2782	−18 55 39·9	0·9090	+1·77	+13·5	3
30	6 6 22	−2 19·51	− 3 38·1	3–3	21 9 15·91	9·2107	−18 31 9 1	0·9113	+1 80	+13·6	4
Dec. 14	6 37 39	−1 43·57	− 2 44·9	6–6	22 21 8·75	9·2513	−11 31 9 3	0·8898	+1·95	+15·0	5
16	6 53 56	+3 24·06	−10 35·6	6–6	22 31 32·30	9·2944	−10 22 5·1	0·8843	+1·96	+15·2	6
18	7 1 42	+2 8·14	− 2 6·6	8–8	22 41 53·68	9·3084	− 9 11 27·5	0·8797	+2·00	+15·3	7
19	6 33 28	−1 57·44	+ 0 26·6	8–8	22 46 56·83	9·2100	− 8 36 17·3	0·8806	+2·04	+15·2	8
20	6 53 59	−1 37·89	+ 0 19·3	9·8	22 52 9·94	9·2765	− 7 59 38·6	0 8766	+2·05	+15·3	9
23	6 54 40	−2 17·95	+ 8 39·3	8–8	23 7 31·47	9·2657	− 6 10 10·0	0 8698	+2·11	+15·3	10
25	6 43 3	−0 52·98	+ 4 16·7	8–8	23 17 39·48	9·2163	− 4 56 47·2	0·8655	+2·14	+15·4	11
27	7 36 54	+1 37·75	− 2 30·7	7–7	23 27 55·70	9·3670	− 3 41 42·2	0·8573	+2·17	+15·5	12
28	8 12 14	−1 14·36	+ 2 58·4	8–8	23 33 5·00	9·4342	− 3 3 26·9	0·8529	+2·21	+15·4	13
29	8 5 34	−1 31·64	+ 7 45·5	8–8	23 38 3·67	9·4205	− 2 26 39·4	0 8511	+2·23	+15·3	14
30	6 29 19	+0 52·80	− 4 17·8	3–3	23 42 43·71	9·1348	− 1 52 40·5	0 8516	+2·24	+15·4	15

November 18.—Comet fairly bright but without marked nucleus.
November 29.—Windy, clock not well heard at times. November 30–December 30.—Comet faint, moonlight.
December 14–16.—Observations difficult owing to the proximity of a small star.
December 23.—Comet faint from haze.
December 27–29.—Observations interrupted by cloud; at times the comet was very faint.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Jan. 12	6 35 20	+1 8·05	− 3 3·8	8–8	0 44 57·12	9·1178	+ 5 44 18·3	0·8062	−0·56 − 5·1	16
20	6 54 18	−2 37·93	− 0 39·7	8–8	1 20 29·72	9·1854	+ 9 50 4·9	0·7776	−0·41 − 5·5	17
26	7 1 32	+4 6·01	− 5 54·9	8–8	1 45 39·96	9·2126	+12 31 34·1	0·7569	−0·37 − 5·5	18
Feb. 12	8 27 9	+1 23·08	+ 0 54·1	7–7	2 50 20·26	9·4549	+18 25 45·3	0·7349	−0·23 − 6·0	19
25	8 33 37	+1 7·85	− 2 35·8	6–6	3 33 45·13	9·4861	+21 25 46·3	0·7181	−0·22 − 6·3	20

January 12.—Comet faint, light clouds passing.
January 20–26.—The comet is still fairly bright but difficult to observe. The R.A. comps. are the more doubtful.
February 12–25.—Comet excessively faint.

Comet VIII. 1886 . . . (*Barnard, January* 23, 1887.)

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Feb. 13	7 19 3	−1 1·98	− 1 26·8	5–5	20 6 55·93	9·5302	+37 59 31·7	0·8895	−1·40 − 3·3	21
16	7 19 44	−1 29·83	− 4 16·9	7–7	20 16 39·26	9·5363	+39 49 22·3	0·8886	−1·39 − 3·9	22
Mar. 11	7 50 18	+2 31·00	+ 0 21·5	2–2	21 41 4·33	9·5590	+52 29 33·4	0·8848	−1·32 − 7·0	23
12	8 20 28	+1 13·07	− 0 14·8	7–7	21 45 16·23	9·4774	+52 58 11·9	0·9011	−1·33 − 7·1	24
16	7 51 53	−0 19·86	+ 4 13·8	7–7	22 1 53·64	9·5811	+54 45 54·4	0·8783	−1·33 − 7·4	25
18	8 14 44	+2 0·72	− 0 56·5	7–7	22 10 30·40	9·5283	+55 37 12·5	0·8896	−1·33 − 7·6	26
Apr. 27	11 48 39	−2 26·33	+ 5 32·8	7–7	1 17 22·61	$9{\cdot}3488_n$	+65 34 43·5	0·8852	−1·54 − 9·4	27
May 14	11 40 13	+3 45·29	+ 6 21·8	8–8	2 31 7·83	$9{\cdot}2377_n$	+66 33 27·4	0·8854	−1·53 −10·3	28
20	11 52 2	−5 18·93	+ 0 19·3	8–8	2 54 43·68	$9{\cdot}3426_n$	+66 39 19·2	0·8818	−1·54 −10·2	29

February 13.—Comet faint from haze.
March 11.—Comet excessively faint, and the observation doubtful in consequence.
March 16.—The comet is small and faint but observation satisfactory.

Comet IX. 1886 . . . (*Barnard-Hartwig.*)

1886.		Greenwich Mean Time. h m s	Comet—Star. Δα m s	Δδ ′ ″	No. of Comps.	Comet's App. R.A. h m s	Log. ($p \times \Delta$)	Comet's App. Dec. ° ′ ″	Log. ($p \times \Delta$)	Red. to App. Place. s ″	Comp. Star.
Oct.	22	16 42 22	−2 6·29	+ 8 5·6	6–6	11 17 42·49	$9·5231_n$	+ 4 3 43·1	0·8305	+ 0·97 − 7·8	30
Nov.	5	16 45 29	+0 20·93	+ 0 34·9	9–8	12 6 3·84	$9·5173_n$	+ 8 0 40·6	0·8153	+ 1·03 − 9·2	31
	7	16 43 55	+2 16·80	+ 1 46·7	8–8	12 14 57·02	$9·5205_n$	+ 8 43 31·0	0·8130	+ 1·03 − 9·4	32
	18	17 10 30	−1 50·10	+ 2 43·0	8–8	13 18 38·12	$9·5212_n$	+ 13 18 46·2	0·7909	+ 0·88 − 8·8	33
	18	17 18 58	−3 28·28	+ 1 21·5	5–6	13 18 40·49	$9·5125_n$	+ 13 18 56·6	0·7880	+ 0·88 − 8·7	34
	23	17 11 29	+0 58·74	− 1 59·0	9–9	13 58 27·51	$9·5424_n$	+ 15 29 23·1	0·7876	+ 0·78 − 7·6	35
	30	17 39 52	+1 32·09	− 7 2·9	8–8	15 7 30·34	$9·5568_n$	+ 17 42 20·0	0·7829	+ 0·61 − 3·6	36
Dec.	1	17 30 6	−2 22·70	− 6 22·7	8–8	15 18 17·05	$9·5670_n$	+ 17 51 47·2	0·7903	+ 0·58 − 2·5	37
	2	17 28 9	−1 5·07	− 4 15·7	8–8	15 29 18·42	$9·5715_n$	+ 17 57 51·7	0·7943	+ 0·57 − 1·7	38
	4	17 38 6	+3 5·85	+ 2 48·9	8–8	15 51 44·89	$9·5736_n$	+ 18 0 4·5	0·7965	+ 0·57 − 0·4	39
	9	17 44 1	−2 31·59	− 3 11·5	8–8	16 47 22·41	$9·5792_n$	+ 17 2 48·5	0·8142	+ 0·58 + 4·6	40
	12	5 56 55	−1 11·39	+ 2 38·0	8–8	17 13 42·68	9·5775	+ 16 2 50·7	0·8300	+ 0·64 + 6·4	41
	14	5 52 47	+1 33·83	+ 7 30·2	7–7	17 33 26·77	9·5761	+ 15 2 53·6	0·8254	+ 0·70 + 7·6	42
	16	6 1 39	−1 59·73	+ 0 11·0	7–7	17 51 59·71	9·5738	+ 13 55 11·9	0·8270	+ 0·76 + 9·2	43
	18	6 9 14	+3 43·67	+ 1 27·7	6–6	18 9 11·45	9·5716	+ 12 41 32·2	0·8288	+ 0·81 + 9·8	44
	19	5 51 59	−0 7·78	+ 5 8·2	8–8	18 17 10·02	9·5676	+ 12 3 47·5	0·8231	+ 0·85 + 10·6	45
	20	6 6 48	+1 15·55	−10 31·7	8–8	18 24 59·31	9·5686	+ 11 24 18·7	0·8280	+ 0·87 + 10·9	46

October 22.—Sky very hazy. The comet rather indistinct, being within the lunar halo.
November 5–December 9.—Windy, clock not well heard.
December 14.—Sky hazy, and the definition at this altitude not good.

1886.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Dec. 23	5 54 51	−1 50·41	− 5 35·5	8–8	18 46 15·23	9·5610	+ 9 25 46·5	0·8262	+0·97	+12·2	47
25	5 54 33	+0 55·71	− 1 21·4	8–8	18 58 59·37	9·5577	+ 8 6 32·2	0·8281	+1·03	+12·4	48
30	5 43 42	−1 7·61	+ 7 58·0	8–8	19 26 22·99	9·5468	+ 4 55 20·2	0·8322	+1·17	+13·3	49
31	5 46 44	+2 16·25	− 1 13·0	7–7	19 31 12·45	9·5475	+ 4 18 19·7	0·8338	+1·18	+13·2	50
1887. Jan. 2	5 39 33	+1 56·57	− 7 10·6	4–4	19 40 19·56	9·5424	+ 3 7 34·6	0·8354	−1·71	+ 5·0	51
8	5 51 14	−1 59·63	+ 0 46·7	4–4	20 4 0·38	9·5479	− 0 8 28·8	0·8418	−1·73	+ 3·2	52
10	5 48 34	+2 44·11	+ 5 16·0	6–6	20 10 53·45	9·5472	− 1 7 42·2	0·8431	−1·72	+ 2·8	53

December 23.—Sky hazy near the horizon and the comet at times, not well seen.
January 2.—Comet faint from haze and moonlight.
January 8.—Comet very faint owing to low altitude and haze.
January 10.—Comet faint and two of the comparisons are rather doubtful.

Comet II. 1887 . . . (*Brooks, January* 23, 1887.)

1887.	Greenwich Mean Time.	Comet—Star. Δα	Comet—Star. Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Feb. 12	7 37 10	−0 53·65	− 1 15·9	8–8	1 23 10·06	0·0810	+75 17 5·0	$0·0379_n$	−0·96	+10·9	54
13	8 13 48	+1 29·89	− 0 59·2	7–7	1 38 0·42	0·0795	+74 14 25·6	$9·6416_n$	−0·80	+10·7	55
15	7 49 28	−2 43·02	− 6 16·1	7–7	2 1 57·31	9·9792	+72 6 13·8	$9·9763_n$	−0·50	+10·2	56

February 12–13.—Windy, clock difficult to hear well.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Feb. 16	8 27 29	−0 35·56	− 6 31·1	8–8	2 12 21·00	9·9912	+70 57 9·8	9·2880$_n$	−0·45	+9·9	57
17	8 6 2	−0 54·91	+ 3 22·4	8–8	2 21 17·33	9·9363	+69 49 57·2	9·7414$_n$	−0.38	+9·5	58
21	8 10 2	+3 25·03	− 10 2·0	3–3	2 49 53·44	9·8385	+65 10 54·1	8·9408$_n$	−0·31	+8·0	59
24	7 53 42	+1 44·17	− 9 31·2	2–2	3 5 40·85	9·7537	+61 43 13·5	8·6602	−0·28	+6·8	60
25	7 43 33	+3 42·14	− 7 9·1	8–8	3 10 12·30	9·7187	+60 35 14·9	8·6426	−0·29	+6·4	61
26	7 53 54	+3 29·51	− 0 3·9	8–8	3 14 28·54	9·7220	+59 27 3·3	9·5439	−0·29	+6·0	62
27	8 20 43	+2 10·66	+ 0 49·9	8–8	3 18 32·78	9·7491	+58 18 24·5	9·9672	−0·29	+5·6	63
28	7 53 43	+2 36·24	− 3 19·2	8–8	3 22 13·42	9·6944	+57 13 27·5	9·8167	−0·29	+5·2	64
Mar. 1	7 19 56	+2 33·16	+ 6 28·1	8–8	3 25 40·21	9·6148	+56 9 47·9	9·5382	−0·30	+4·8	65
2	7 27 34	−2 42·03	− 0 3·4	4–4	3 29 2·93	9·6213	+55 4 53·8	9·7801	−0·27	+4·4	66
6	8 25 5	+0 48·40	− 7 25·8	9–9	3 41 4·31	9·6822	+50 54 10·3	0·3100	−0·33	+2·9	67
10	7 47 54	−2 16·61	− 2 41·2	7–7	3 51 1·21	9·6032	+47 5 7·5	0·3195	−0·35	+1·3	68
11	8 39 48	−1 3·69	+ 9 16·9	8–8	3 53 23·98	9·6664	+46 8 36·9	0·4717	−0·37	+0·9	69
12	9 3 17	−2 1·66	− 5 6·4	8–8	3 55 38·34	9·6814	+45 13 38·1	0·5389	−0·37	+0·6	70

February 21.—Observation obtained with difficulty between clouds.
March 2.—Comet very faint from haze and moonlight. Observation somewhat uncertain.
March 6–30.—Comet rather faint in moonlight.
March 10.—Comet in close proximity to several small stars. Observation a little uncertain.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p+\Delta$)	Comet's App. Dec.	Log. ($p\times\Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Mar. 14	8 30 28	−0 59·75	+ 8 1·5	8–8	3 59 48·49	9·6426	+43 30 46·4	0·5073	−0·40	−0·2	71
16	10 15 39	+1 19·07	− 5 23·6	6–8	4 3 56·69	9·6883	+41 47 8·1	0·7052	−0·43	−0·8	72
18	10 37 16	+2 20·48	+ 6 56·9	8–8	4 7 44·28	9·6763	+40 11 1 7	0·7481	−0·45	−1·5	73
23	8 15 48	+1 22·17	− 5 2·7	8–8	4 16 18·60	9 6024	+36 33 5·2	0·6081	−0·50	−3·0	74
25	9 50 42	−2 5·87	+ 7 36·3	8–8	4 19 41·16	9·6477	+35 8 23·6	0·7416	−0·50	−3·6	75
27	8 35 55	+1 34·96	− 5 27·7	8–8	4 22 45·41	9·6132	+33 51 12·1	0·6722	−0·54	−4·0	76
28	8 11 1	−1 20 49	+ 3 12·8	8–8	4 24 15·87	9·5916	+33 13 46·8	0 6521	−0·53	−4·3	77
30	8 52 58	+0 36·81	+ 4 25·2	9–9	4 27 19·77	9·6185	+31 58 32·5	0·7135	−0·56	−4·8	78
Apr. 10	9 52 19	+3 22·44	+ 8 50·8	4–4	4 42 37·35	9·6034	+25 58 28·3	0·8164	−0·65	−7·1	79
11	9 31 27	+2 44·05	− 6 41·7	8–8	4 43 54·75	9·6049	+25 29 22·4	0 8053	−0·66	−7·2	80
15	9 5 49	+1 12·30	− 6 23·7	3–3	4 48 58·26	9·5990	+23 38 32·6	0·8013	−0·68	−7·8	81
16	9 7 8	+0 28 03	+ 5 9·8	8–8	4 50 13·51	9·5976	+23 12 8·1	0·8053	−0·68	−8·0	82
17	9 23 52	−1 17·17	− 8 41·2	8–8	4 51 28·96	9·5945	+22 45 9·9	0·8187	−0 68	−8·1	83
20	9 15 54	−1 11·71	+ 3 26·1	6–6	4 55 8·08	9·5906	+21 28 56 7	0·8220	−0·70	−8·5	84
23	9 24 10	−2 21·97	− 0 4·5	5–5	4 58 44·50	9·5832	+20 15 53·3	0·8334	−0·71	−8·8	85

March 23–27–28.— Sky clear, a high wind prevailing.
April 10.—Comet excessively faint upon the Moon rising.
April 11.—Definition bad.
April 20–23.—The comet has become very faint and of low altitude. The R.A. comparisons are rather uncertain.

Comet III. 1887 . . . (*Barnard, February* 16, 1887.)

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Feb. 28	9 1 56	−1 20·59	+ 4 55·6	8–8	4 43 18·03	9·4402	+22 52 11·7	0·6882	+0·10	−6·8	86
Mar. 13	8 34 46	−1 8·39	+ 2 14·6	8–8	3 37 24·29	9·5962	+32 7 12·7	0·6752	−0 47	−3 8	87
14	9 11 32	+1 35·48	+ 0 53·2	5–5	3 34 35·54	9·6245	+32 27 13·0	0 7187	−0·51	−3·8	88
16	8 44 14	+3 31·71	+ 3 47·6	7–7	3 29 37·55	9 620.4	+33 2 13·7	0·6990	−0·58	−3·8	89
18	8 58 4	+1 16·95	+ 2 26 8	7–7	3 25 11·14	9·6341	+33 32 40·0	0·7235	−0·62	−3·8	90
19	8 33 2	−2 30·15	+ 3 13·0	8–8	3 23 12·24	9 6276	+33 45 59·8	0·7012	−0·63	−3·9	91
23	9 0 2	−2 16·45	+10 6·5	8–8	3 16 2·12	9·6451	+34 33 20·0	0·7501	−0·73	−4·1	92
27	9 21 53	−1 21·82	+ 2 54·2	8–8	3 10 6·49	9·6430	+35 10 55·8	0·7906	−0·81	−4·5	93
Apr. 10	9 12 36	+2 47·47	− 0 29·7	3–3	2 55 10 80	9·6162	+36 39 46·4	0·8398	−0·99	−6 2	94

February 28.—Comet excessively faint from fog and moonlight. No central condensation visible.
March 14.—Sky hazy: the comet is a diffused mass of light and affords no distinct point for bisection.
March 16.—The comet was better seen and a very faint nucleus was discernible towards the following side.
March 27.—A faint star near the comet rendered the observation rather difficult and uncertain.

Comet IV. 1887 . . . (*Barnard, May* 12, 1887.)

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. St r.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
June 9	11 11 31	−1 2·48	−5 19·0	8–8	16 4 17·81	8 5908	−11 3 21·6	0 8951	+2·07	+ 2·0	95
10	10 51 7	−1 53·79	+5 13·8	8–8	16 6 28·99	7·9455	−10 17 6 1	0·8924	+2 07	+ 2·2	96
12	11 37 5	−1 46·30	+3 56·7	8–8	16 10 59·75	8 9413	− 8 43 31·5	0 8846	+2·07	+ 2·8	97
13	10 58 3	+1 17·06	+0 34·2	8–8	16 13 10·87	8·4459	− 7 59 35·7	0·8827	+2·06	+ 2·9	98

June 9.—Comet small, fairly bright, and with distinct nucleus.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. $p\times\Delta$	Comet's App. Dec.	Log. $(p\times\Delta)$	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
• June 15	12 28 8	+1 20·97	+7 25·5	6–6	16 17 48·40	9·2323	− 6 28 18·4	0·8717	+2·06 + 3·4	99
17	11 2 12	−1 1·07	+6 27·6	8–8	16 22 10·35	8·6556	− 5 5 30·1	0·8691	+2·06 + 4·0	100
18	10 54 51	−1 53·33	−9 24·5	8–8	16 24 25·24	8·5582	− 4 24 32·8	0·8657	+2·07 + 4·3	101
20	10 57 0	+1 16·09	+4 15·5	8–8	16 28 56·76	8·6523	− 3 4 9·6	0·8587	+2·06 + 4·7	102
22	12 25 32	−1 24·16	+0 28·7	8–8	16 33 36·18	9·2612	− 1 46 5·7	0·8505	+2·07 + 5·3	103
July 11	10 52 34	+0 11·05	−4 40·2	9–9	17 15 31·28	8·9775	+ 6 28 28·5	0·7996	+2·11 +10·0	104
12	11 29 33	−1 15·54	+6 46·8	9–9	17 17 42·21	9·1855	+ 6 44 23·7	0·8062	+2·12 +10·2	105
13	11 14 21	−5 22·07	+7 23·7	7–7	17 19 48·11	9·1259	+ 6 58 37·2	0·7975	+2·14 +10·5	106
14	11 19 1	+3 58·89	−0 11·5	8–8	17 21 55·30	9·1565	+ 7 11 58·9	0·7965	+2·11 +10·5	107
18	11 3 34	−4 17·36	+4 21·4	8–8	17 30 14·31	9·1195	+ 7 56 22·6	0·7904	+2·15 +11·6	108
19	11 40 25	+3 52·14	−5 59·3	8–8	17 32 21·30	9·2732	+ 8 5 22·4	0·7932	+2·12 +11·6	109
20	11 19 13	−3 11·85	+6 34·5	8–7	17 34 22·76	9·2051	+ 8 13 36·2	0·7901	+2·15 +11·9	110
21	11 25 14	−1 42·06	−8 40·0	9–9	17 36 26·24	9·2350	+ 8 20 47·6	0·7902	+2·14 +12·1	111
24	11 17 30	−3 10·89	+5 3·1	8–8	17 42 30·48	9·2281	+ 8 38 56·7	0·7879	+2·16 +12·7	112
27	12 11 54	+1 5·23	+0 42·8	8–8	17 48 36·44	9·3950	+ 8 51 3·1	0·7952	+2·14 +13·2	113
28	12 7 31	+3 3·90	+3 21·4	4–4	17 50 35·10	9·3901	+ 8 53 41·9	0·7945	+2·14 +13·3	113

June 15.—Comet faint, sky hazy.

July 13.—Windy, clock difficult to hear well.

July 20.—Comet faint and difficult to observe. Sky less transparent than usual.

July 27.—Comet faint and observation rather uncertain.

July 28.—The comet has become faint and difficult to observe, especially in declination, owing to its peculiar form. It is much elongated from N. to S., and narrow from W. to E. This peculiarity has been noticed on several occasions lately.

All the above observations have been made with a dark-bar micrometer and an equatorial refractor of 10 inches aperture. They are corrected for differential refraction throughout.

*Assumed Mean Places of Comparison Stars.**

Comet VII. 1886.

Comp. Star.	R.A. 1886·0. h m s	Decl. 1886·0. ° ′ ″	Authority.
1	20 9 53·74	−22 49 8·5	Equat. comparison with Arg. Oe_2 20264.
2	20 37 47·13	−20 47 16·5	Equat. comparisons with Arg. Oe_2 20832 and C.Z. 28388.
3	21 3 4·74	−18 52 50·7	Equat. comparisons with Arg. Oe_2 21180 and Lam. 1353.
4	21 11 33·62	−18 27 44·6	⅓ (Gr. 7 yr. 2411 + Arm_1 4607 + C.Z. 29215).
5	22 22 50·37	−11 28 39·3	Equat. comparison with 58 Aquarii.
6	22 28 6·28	−10 11 44·7	⅓ (Yarn. 9908 + Arm_1 4956 + Glasg. 5871).
7	22 39 43·54	− 9 9 36·1	Equat. comparisons with Lam. 3956 and $B.W._1$ 780.
8	22 48 52·24	− 8 36 59·1	Schj. 9392.
9	22 53 45·78	− 8 0 13·1	Lam. 4690.
10	23 9 47·31	− 6 19 4·6	⅓ (2 Yarn. 10242 + $B.W._1$ 142).
11	23 18 30·32	− 5 1 19·2	Equat. comparison with $B.W._1$ 302.
12	23 26 15·78	− 3 39 27·0	$B.W._1$ 491 (Lalande's R.A. is 0ˢ·75 greater).
13	23 34 17·15	− 3 6 40·7	Equat. comparison with Lam. 4769.
14	23 39 33·08	− 2 34 40·3	Equat. comparison with $B.W._1$ 812.
15	23 41 48·67	− 1 48 38·1	Equat. comparison with Lam. 9283.
	1887·0.	1887·0.	
16	0 43 49·63	+ 5 47 27·2	B.B. vi. + 5°·109.
17	1 23 8·06	+ 9 50 50·1	$B.W._1$ 356.
18	1 41 34·32	+12 37 34·5	$B.W._1$ 716.
19	2 48 57·41	+18 24 57·2	Equat. comparison with $B.W._2$ 1097.
20	3 32 37·50	+21 28 28·4	$B.W._2$ 655.

Comet VIII. 1886.

	1886·0	1886·0	
21	20 7 59·31	+38 1 1·9	¼ (3 $Arm._2$ 2596 + Lal. 38806).
22	20 18 10·48	+39 53 43·0	γ *Cygni*, *Newcomb. Stand. Cat.* 905.
23	21 38 34·65	+52 29 18·9	Arg. $Oe._1$ 22732-3.
24	21 44 4·49	+52 58 33·8	Arg. $Oe._1$ 22887.
25	22 2 14·83	+54 41 48·0	½ (Arg. $Oe._1$ 23418-9 + Rümker 9852).
26	22 8 31·01	+55 38 16·6	Equat. comparison with Arg. Oe_1 23565-6.
27	1 19 50·48	+65 29 20·1	Lal. 2540. Orange-coloured star = No. 19 Chambers' Catalogue of red stars, *Monthly Notices*, xlvii. 6.
28	2 27 24·07	+66 27 15·9	Equat. comparison with Arg. $Oe._1$ 2644.
29	3 0 4·15	+66 39 10·1	Equat. comparisons with Arg. $Oe._1$ 3564 and B.B. vi. + 66°·249.

* These stars will be observed, as far as possible, on the Meridian at Harrow.—G. L. T.

Comet IX. 1886.

Comp. Star.	R.A. 1886·0. h m s	Decl. 1886·0. ° ′ ″	Authority.
30	11 19 47·81	+ 3 55 45·3	¼ (Gr. 7 yr. 1377 + Arm.$_1$ 2477 + Glasg. 2943 + Sant. 784).
31	12 5 41·88	+ 8 0 14·9	Yarn. 5085 (B.W.$_1$ 49, which is the same star, has greater declination by 3′ 6″·8).
32	12 12 39·19	+ 8 41 53·7	¼ (Gr. 6 yr. 793 + Arm$_1$ 2636 + Sant. 838 + Lal. 23048).
33	13 20 27·34	+13 16 12·0	Equat. comparison with * 34.
34	13 22 7·89	+13 17 43·7	⅕ (2 Glasg. 3382 + Schj. 4814 + B.W.$_1$ 325 + Lal. 24912).
35	13 57 27·99	+15 31 29·7	B.W.$_2$ 1229.
36	15 5 57·64	+17 49 26·6	B.W.$_2$ 80 (B.W.$_2$ 53 is the same star with an error of 1^m).
37	15 20 39·17	+17 58 12·4	Lal. 28144.
38	15 30 22·92	+18 2 9·1	½ (Gr. 9 yr. 1392 + Yarn. 6424).
39	15 48 38·48	+17 57 16·0	½ (B.W.$_2$ 1176 + Lal. 28961).
40	16 49 53·42	+17 5 55·4	Equat. comparison with B.B. vi. + 17″·310 7
41	17 14 53·43	+16 0 6 3	⅓ (2 Arm.$_2$ 2043 + B.W.$_2$ 365).
42	17 31 52·24	+14 55 15·8	½ (B.W.$_2$ 929 + Lal. 32124). The mean of Bessel's rather discordant observations is taken. It does not agree with Lalande's).
43	17 53 58 68	+13 54 51·6	⅓ (2 Arm.$_2$ 2136 + B.W.$_1$ 1092).
44	18 5 26·97	+12 39 54·8	B.W.$_1$ 67.
45	18 17 16·95	+11 58 28·8	½ (Wash. Obs. + Lal. 33895).
46	18 23 42·89	+11 34 39·5	½ (B.B. vi. + 11″·3478 + Rümker 6524).
47	18 48 4·67	+ 9 31 9·8	½ (Glasg. 4632 + Arm.$_2$ 2299).
48	18 58 2·63	+ 8 7 41·2	¼ (2 Glasg. 4689 + B.W.$_1$ 1445 + Lal., 35624).
49	19 27 29·43	+ 4·47 8·9	½ (Glasg. 4825 + Arm.$_1$ 4091).
50	19 28 55·02	+ 4 19 19·5	Lam. 4376.
	1887·0.	1887·0.	
51	19 38 24·70	+ 3 14 40·1	½ (Lam. 4559 + B.W.$_1$ 947).
52	20 6 1·74	− 0 9 18·7	½ (Lam 7343 + Piazzi 18).
53	20 8 11·06	− 1 13 1·0	Lam. 7361. The decl. of Lal. 38760, which is the same star, is 19″·4 greater.

Comet II. 1887.

	1887·0	1887·0	
54	1 24 4·67	+75 18 9·9	Equat. comparison with Fedorenko 268.
55	1 36 31·33	+74 15 14·2	⅓ (2 Rad.$_1$ 503 + Arg. Oe$_1$ 1866).
56	2 4 40·83	+72 12 19·7	Equat. comparison with Arg. Oe$_1$ 2705.
57	2 12 57·01	+71 3 31·0	Equat. comparisons with B.B. vi. + 70″·187 and + 71″·139.

Comp. Star.	R.A. 1887·0.	Decl. 1887·0.	Authority.
	h m s	° ′ ″	
58	2 22 12·63	+69 46 25·4	B.B vi. + 69°·155.
59	2 46 28·72	+65 20 48·0	Rad.$_1$ 814.
60	3 3 56·96	+61 52 37·9	Equat. comparisons with B.B. vi. + 61°·521 and 543.
61	3 6 30·45	+60 42 17·5	Arg. Oe$_1$ 3563.
62	3 10 59·32	+59 27 1·2	A. G. Zones 408.
63	3 16 22·41	+58 17 29·0	Arg. Oe$_1$ 3731.
64	3 19 37·48	+57 16 41·4	Arg. Oe$_1$ 3772.
65	3 23 7·36	+56 3 15·1	Lal. 6364.
66	3 31 45·23	+55 4 52·7	B.B. vi. + 54°·701.
67	3 40 16·24	+51 1 33·2	½ (Rad.$_1$ 1068 + Arg. Oe$_1$ 4135).
68	3 53 18·17	+47 7 47·4	½ (2 Arm.$_2$ 491 + Lal. 7322).
69	3 54 28·04	+45 59 19·2	Equat. comparisons with Rümker, 2024 and B.B. vi. + 45°·857.
70	3 57 40·37	+45 18 44·0	B.W.$_2$ 1181.
71	4 0 48·64	+43 22 45·0	B.W.$_2$ 1255.
72	4 2 38·05	+41 52 32·5	B.W.$_2$ 1296.
73	4 5 24·25	+40 4 6·3	Lal. 7752.
74	4 14 56·93	+36 38 10·8	B.W.$_2$ 259.
75	4 21 47·53	+35 0 50·9	½ (B.B. vi. + 34°·883 + B.W.$_2$ 416).
76	4 21 10·98	+33 56 43·8	½ (B.W.$_2$ 409 + Lal. 8346).
77	4 25 36·89	+33 10 38·3	Equat. comparison with B.B. vi. + 33°·872.
78	4 26 43·52	+31 54 12·1	B.W.$_2$ 527.
79	4 39 15·56	+25 49 44·7	½ (B.W.$_2$ 822 + Lal. 8917).
80	4 41 11·37	+25 36 11·4	B.W.$_2$ 868.
81	4 47 46·64	+23 45 4·2	B.W.$_2$ 1024.
82	4 49 46·17	+23 7 6·2	B.W.$_2$ 1073.
83	4 52 46·82	+22 53 59·1	B.B. vi. + 22°·792.
84	4 56 20·49	+21 25 39·0	*Newcomb. Stand. Cat.* 239.
85	5 1 7·18	+20 16 6·6	*Newcomb. Stand. Cat.* 242.
		Comet III. 1887.	
	1887·0	1887·0	
86	4 44 38·52	+22 47 22·9	B.B. vi. + 22°·764.
87	3 38 33·15	+32 5 1·9	B.B. vi. + 31°·645.
88	3 33 0·57	+32 26 23·6	B.W.$_2$ 663.
89	3 26 6·42	+32 58 29·8	½ (B.W.$_2$ 499 + Lal. 6491).
90	3 23 54·81	+33 30 17·0	B.W.$_2$ 447.
91	3 25 43·02	+33 42 50·7	Equat. comparison with B.W.$_2$ 512.
92	3 18 19·30	+34 23 17·6	Equat. comparisons with B.W.$_2$ 306 and 381.

Comp. Star.	R.A. 1887·0. h m s	Decl. 1887·0. ° ′ ″	Authority.
93	3 11 20·12	+35 8 6·1	½ (B.W.$_2$ 199 + Lal. 6055).
94	2 52 24·32	+36 40 22·2	Equat. comparison with B.B. vi. + 36°·608.
		Comet IV. 1887.	
95	16 5 18·22	−10 58 4·5	Equat. comparison with B.W.$_1$ 63.
96	16 8 20·71	−10 22 22·1	½ (2 Yarn. 6715 + B.W.$_1$ 111).
97	16 12 43·98	− 8 47 30 9	½ (2 Schj. 5761 + Lal. 29697).
98	16 11 51·74	− 8 0 12·7	B.W.$_1$ 184.
99	16 16 25·37	− 6 35 47·2	½ (B.W.$_1$ 272 + Schj. 5779).
100	16 23 9·36	− 5 12 1 6	½ (2 Schj. 5822 + Lal. 29982).
101	16 26 16·50	− 4 15 12·7	Schj. 5841.
102	16 27 38·61	− 3 8 29·8	Equat. comparison with Schj. 5851.
103	16 34 58·27	− 1 46 39·7	½ (Schj. 5901 + Lam. 5252).
104	17 15 18·12	+ 6 32 58·7	½ (2 Glasg. 4271 + B.W.$_1$ 236).
105	17 18 55·62	+ 6 37 26·8	Arm.$_2$ 2052.
106	17 25 8·04	+ 6 51 3·0	B.B. vi. + 6°·3434.
107	17 17 54·30	+ 7 11 59·9	B.B. vi. + 7°·3355.
108	17 34 29·53	+ 7 51 49·7	½ (Glasg. 4351 + Schj. 6332).
109	17 28 27·04	+ 8 11 10·1	Lal. 31996.
110	17 37 32·46	+ 8 6 49·8	½ (B.W.$_1$ 701 + Lal. 32337).
111	17 38 6·16	+ 8 29 15·4	B.B. vi. + 8°·3478.
112	17 45 39·21	+ 8 33 41·0	½ (Glasg. 4405 + Schj. 6418).
113	17 47 29·06	+ 8 50 7·2	B.B. vi. + 8°·3526.

Col. Tomline's Observatory, Orwell Park:
1887. *October* 19.

Occultation of Regulus by the Moon, observed at Dunsink Observatory. Communicated by Sir R. S. Ball, LL.D., F.R.S.

The occultation of *Regulus* by the Moon, which took place on October 12, was observed here with the 12-inch equatorial by Mr. Arthur A. Rambaut. The disappearance occurred at

16^h 16^m 54^s·2 Dunsink mean time.

The star suffered no perceptible diminution of brightness as it approached the bright limb of the Moon. It appeared to enter undimmed for a short distance within the disc, and was then suddenly extinguished.

The reappearance occurred at

17^h 20^m 36^s·0 Dunsink mean time.

The star flashed out in full brilliance with a suddenness almost startling.

Dunsink Observatory: October 17, 1887.

Occultation of Regulus. By the Rev. S. J. Johnson, M.A.

In contrast to the clouded state of the sky when *Aldebaran* was occulted on the 7th, a perfectly clear air prevailed during immersion of *Regulus* on the morning of the 13th. Disappearance $4^h\ 41^m\ 50^s$ morn. (time taken by sextant only.) But the point of interest was that the star assumed the appearance of visibility through the bright disc of the Moon during three beats of the chronometer ($1\frac{1}{2}$ second) before finally vanishing. Employed a power of 50 on $3\frac{1}{4}$ inches. *Mars* was included in the field of the finder, contrasting not a little in tint with the whiteness of *Regulus* and the yellow lunar disc. Emersion through haze at $5^h\ 47^m\ 19^s$. This might have been observed with the naked eye in a clear sky, as the star was readily visible to unaided vision directly afterwards.

Melplash Vicarage, Bridport:
October 22.

Note on the Latitude and Longitude of Maresfield Observatory.
By Captain W. Noble.

After the erection of my observatory I determined its geographical coordinates (by the best means then at my disposal) as follow:—

Latitude 51° 0′ 58″·3 N., and
Longitude 17·5 seconds E.;

and these quantities appear in every communication of mine to the Society (in which they were involved) up to the year 1874.

In 1873, however, the Ordnance Survey of the county of Sussex for the 25-inch map was completed, and at the end of that year I applied to the Director-General for the position of a bench mark made at the time. In reply I was furnished with a position (as it has since turned out) 3″·5 in error in latitude, and 10″·1 wrong in longitude = 355 feet and 646 feet respectively; but I altered my assumed coordinates in accordance with it.

Recently the present Director-General of the Ordnance Survey has obligingly furnished me with the absolutely accurate place of the bench mark of which I have spoken, and triangulating from it to the centre of my transit pier I find that to be situated in

Latitude 51° 0′ 59″·8 N., and
Longitude 17·11 seconds E.;

a determination in which I have the highest confidence.

Ephemeris for Physical Observations

Greenwich Noon		Angle of Position of ♃'s Axis. P	Latitude of Earth above ♃'s Equator. B	Latitude of Sun Equator. *B*	Annual Parallax. A−L.	L−O.	Longitude of ♃'s Central Meridian. (878°·25) I.	(870·27) II	Corr. for Phase.
1887.		°	°	°	°	°	°	°	°
Dec.	24	13·923	−2·990	−3·060	−6·202	100·800	21·23	86·11	+0·168
	29	13·552	2·999	3·058	6·794	101·779	91·76	116·74	·201
1888.									
Jan.	3	13·189	−3·007	−3·056	−7·358	102·728	162·34	147·42	+0·236
	8	12·834	3·015	3·054	7·889	103·644	232·98	178·16	·271
	13	12·489	3·023	3·052	8·383	104·525	303·67	208 95	·306
	18	12·157	3·031	3·050	8·837	105·366	14·42	239·79	·340
	23	11·838	3·038	3·048	9·247	106·163	85·23	270·70	·372
	28	11·535	3·046	3·045	9·610	106·913	156·10	301·66	·402
Feb.	2	11·251	−3·054	−3·042	−9·924	107·613	227·03	332·69	+0·429
	7	10·987	3·062	3·040	10·183	108·259	298·03	3 79	·451
	12	10·744	3·070	3·037	10·384	108·848	9·09	34·95	·469
	17	10·525	3·078	3·034	10·523	109·375	80·22	66·17	·482
	22	10·333	3·085	3·030	10·598	109·837	151·42	97·47	·489
	27	10·168	3·093	3·027	10·605	110·231	222·69	128·83	·489
Mar.	3	10·032	−3·101	−3·023	−10·541	110·555	294·02	160·26	+0·483
	8	9·926	3·109	3·020	10·404	110·806	5·43	191·76	·471
	13	9·852	3·117	3·016	10·191	110·982	76·90	223·33	·452
	18	9 810	3·125	3·012	9·901	111·080	148·44	254·97	·427
	23	9·801	3·132	3·008	9·532	111·100	220·05	286·67	·395
	28	9·825	3·139	3·004	9·085	111·042	291·72	318·43	·359
Apr.	2	9·882	−3·146	−2·999	−8·560	110·906	3·44	350·26	+0·319
	7	9·970	3·151	2·995	7·959	110·694	75·22	22·14	·276
	12	10·089	3·156	2·990	7·284	110·409	147·05	54·06	·231
	17	10·237	3·159	2 985	6·539	110·053	218·93	86·03	·186
	22	10·412	3·161	2·980	5·729	109·633	290·84	118·04	·143
	27	10 610	3·161	2·975	4·861	109·156	2·77	150·08	·103
May	2	10·827	−3·160	−2·970	−3·944	108·628	74·72	182·13	+0·068
	7	11·061	3·157	2·965	2·983	108·057	146·68	214·19	·039
	12	11·307	3·152	2·959	1·988	107·453	218·64	246·24	·017
	17	11·561	3·145	2·954	−0·972	106·829	290·58	278·28	+0·004
	22	11·817	3·135	2·948	+0·054	106·193	2·49	310·29	...
	27	12·071	3·123	2·942	1·081	105·557	74·37	342·27	−0·005
June	1	12·320	−3·110	−2·936	+2·098	104·932	146·20	14·20	·019
	6	12·559	3·095	2·930	3·093	104·329	217·97	46·07	−0·042
	11	12·784	3·078	2·924	4 056	103·757	289·67	77·87	·072

of Jupiter, 1888. By A. Marth.

Greenwich Noon.		Diameter Equat.	Polar.	Difference of limbs in A.R.	in Decl.	Defect of illumination. Equat. preced. limb.	in A.R.	in Decl. north l.	*d*	*w*
1887.		″	″	s	″	″	s	″	°	°
Dec.	14	31·75	29·74	2·223	29·86	0·09	0·006	0·01	6·19	270·87
	29	32·02	29·99	2·245	30·10	·11	·007		6·78	·76
1888.										
Jan.	3	32·32	30·26	2·269	30·37	0·13	0·009	0·01	7·35	270·65
	8	32·64	30·56	2·295	30·67	·15	·010		7·88	·55
	13	32·99	30·89	2·323	30·99	·18	·012		8·37	·45
	18	33·37	31·25	2·353	31·34	·20	·013		8·82	·38
	23	33·77	31·63	2·384	31·72	·22	·015		9·23	·33
	28	34·20	32·03	2·417	32·12	·24	·016		9·59	·27
Feb.	2	34·65	32·46	2·451	32·55	0·26	0·018	0·01	9·91	270·21
	7	35·15	32·91	2·487	33·00	·28	·019		10·17	270·15
	12	35·66	33·39	2·525	33·47	·29	·020		10·37	270·10
	17	36·19	33·89	2·564	33·97	·30	·021		10·51	270·05
	22	36·74	34·41	2·605	34·48	·31	·022		10·58	269·99
	27	37·31	34·94	2·647	35·01	·32	·022		10·59	269·92
Mar.	3	37·89	35·49	2·689	35·56	0·32	0·022	0·01	10·52	269·85
	8	38·49	36·05	2·732	36·12	·32	·022		10·39	·77
	13	39·10	36·61	2·776	36·69	·31	·021		10·17	·69
	18	39·71	37·18	2·819	37·26	·29	·020		9·88	·59
	23	40·31	37·75	2·862	37·83	·27	·019		9·52	·48
	28	40·91	38·31	2·905	38·39	·25	·018		9·07	·35
Apr.	2	41·50	38·86	2·946	38·94	0·23	0·016	0·01	8·55	269·19
	7	42·06	39·39	2·985	39·47	·20	·014	·01	7·95	269·01
	12	42·60	39·89	3·022	39·98	·17	·012	·00	7·27	268·81
	17	43·10	40·36	3·056	40·45	·13	·010		6·53	268·56
	22	43·55	40·78	3·086	40·88	·11	·008		5·72	268·23
	27	43·95	41·16	3·112	41·26	·08	·006		4·86	267·78
May	2	44·29	41·48	3·134	41·58	0·05	0·004		3·94	267·16
	7	44·57	41·74	3·152	41·84	·03	·002		2·98	266·1
	12	44·78	41·94	3·164	42·05	·01	·001		2·00	264·1
	17	44·91	42·06	3·171	42·18	·00	·000		0·99	258·2
	22	44·97	42·12	3·172	42 24	on following limb		on south limb	0·21	164·9
	27	44·95	42 10	3·168	42·23				1·10	100·1
June	1	44·86	42 01	3·159	42·14	0·01	0·001		2·10	95·0
	6	44·69	41·85	3·144	41·99	·03	·002		3·09	93·2
	11	44·45	41·63	3·125	41·77	·06	·004	0·00	4·05	92·21

Greenwich Noon		Angle of Position of ♃'s Axis. P	Latitude of Earth above ♃'s Equator. B	Latitude of Sun above ♃'s Equator. *B*	Annual Parallax. A−L.	L−O.	Longitude of ♃'s Central Meridian. (873°·25) I.	(870°·27) II.	Corr. for Phase.
1888.		°	°	°	°	°	°	°	°
June	16	12·991	3·059	2·917	4·977	103·227	1·30	109·60	·108
	21	13·178	3·040	2·910	5·850	102·747	72·84	141·25	·149
	26	13·342	3·020	2·903	6·666	102·324	144·29	172·80	·194
July	1	13·481	−3·000	−2·896	+7·419	101·963	215·66	204·27	−0·240
	6	13·594	2·980	2 889	8·104	101·671	286·93	235·64	·286
	11	13·679	2·959	2·882	8·717	101·450	358·11	266·92	·331
	16	13·736	2·938	2·875	9·256	101·304	69·19	298·10	·373
	21	13·764	2·917	2·868	9·720	101·234	140 17	329·19	·411
	26	13·763	2·898	2·860	10·108	101·240	211·06	0·19	·445
	31	13·734	2·879	2·852	10·420	101·321	281·87	31·10	·473
Aug.	5	13·676	−2·860	−2·844	+10·658	101·477	352·59	61·92	−0·494
	10	13·590	2·842	2·836	10·822	101·708	63·23	92·66	·509
	15	13·476	2·825	2·828	10·914	102·011	133·79	123·33	·518
	20	13·335	2·809	2·820	10·936	102·383	204·28	153·92	·520
	25	13·168	2·794	2·812	10·892	102·821	274·71	184·45	·515
	30	12·975	2·780	2·803	10·785	103·323	345·07	214·92	·506
Sept.	4	12·757	−2·776	−2·794	+10·618	103·886	55·38	245·33	−0·491
	9	12·515	2·752	2·785	10·393	104·507	125·64	275·69	·470
	14	12·249	2·739	2·776	10·113	105·183	195·85	306·00	·445
	19	11·959	−2·726	−2·767	+9·782	105·909	266·01	336·27	−0·419

The angle A−L is the difference of the jovicentric longitudes of the Sun and Earth, reckoned in the plane of *Jupiter's* equator; L−O+180° the jovicentric longitude of the Earth reckoned from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or the point of the ascending node of the planet's orbit on its equator.

Two values of the "longitude of ♃'s central meridian" are given for each date: the first, computed with the daily rate of rotation 878°·25, being intended for comparing the observations of the white spots in the neighbourhood of the planet's equator; the second, computed with the rate 870°·27, for the observations of the remnant of the great reddish spot in the planet's southern hemisphere. These rates, and the deduced longitudes, conform with those adopted in the ephemeris for the last apparition of *Jupiter* (*Monthly Notices*, vol. xlvii. page 40). The few passages of the great spot across the middle of the disc, observed in the course of the last apparition, render it probable that the spot will be found near the adopted zero meridian of the second system of longitudes. But as any observations of the white spots which may have been made during the last season have

Greenwich Noon.	Diameter Equat.	Diameter Polar.	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat.	in A.R. following limb.	in Decl. south l.	d	w
1888.	″	″	s	″	″	s	″	°	°
June 16	44·15	41·34	3·101	41·49	·08	·006	·01	4·97	91·62
21	43·78	41·00	3·074	41·15	·11	·008	·01	5·84	91·20
26	43·36	40·61	3·043	40·76	·15	·010	·01	6·66	90 88
July 1	42·90	40·17	3 009	40·33	0·18	0·012	0·01	7·41	90·65
6	42·40	39·70	2·973	39·86	·21	·014	·01	8·09	90·46
11	41·87	39·21	2·935	39·36	·24	·016	·01	8·70	90·30
16	41·32	38·69	2·896	38·84	·27	·018	·02	9·24	90·17
21	40·75	38 16	2·856	38·31	·29	·019	·02	9·71	90·05
26	40·17	37·62	2·816	37·77	·31	·021	·02	10·10	89·96
31	39·59	37·07	2·776	37·22	·33	·022	·02	10·41	89·88
Aug. 5	39 01	36 53	2·736	36·67	0·34	0·022	0·02	10·64	89·81
10	38·43	35·99	2·697	36·13	·34	·023	·02	10·81	89·75
15	37·86	35·46	2·659	35·59	·34	·023	·02	10·90	89·70
20	37·31	34·94	2·622	35 07	·34	·023	·02	10·92	89·65
25	36·78	34·44	2·586	34·57	·33	·022	·02	10·88	89·62
30	36·26	33·96	2·552	34·08	·32	·022	·02	10·77	89·59
Sept. 4	35·76	33·49	2·519	33·60	0·31	0·021	0·01	10·60	89·56
9	35·28	33·04	2·488	33·15	·29	·020	·01	10·38	89·54
14	34 83	32·62	2·459	32 72	·27	·018	·01	10·10	89·52
19	34·40	32·22	2·432	32·31	0·25	0·017	0 01	9·77	89·49

not yet come to my knowledge, it is uncertain how far the chief white spot may have moved away from the neighbourhood of the zero meridian of the first system, and due allowance must be made for this uncertainty. The differences of successive values of the longitudes of 𝔏's central meridian amount, for the intervals of five days, to 12 rotations in addition to the differences directly deduced; so that, for instance, the differences of the values for December 29 and December 24 are 4390°·53 and 4350°·63. The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc. A list of Greenwich times when these latter longitudes are 0° will be found further on.

The diameters of the disc, &c. depend on the same assumed values as in the ephemerides for preceding apparitions. The formulæ employed may be found in vol. xlv. page 508.

The inclinations γ and the ascending nodes Γ of the orbits of the four satellites of *Jupiter* in reference to the plane of the planet's equator are the following, the longitudes of the nodes being reckoned from O, the point of the ascending node of *Jupiter's* orbit on the equator.

1888	Sat. I. γ_1	Sat. I. Γ_1	Sat. II. γ_2	Sat. II. Γ_2	Sat. III. γ_3	Sat. III. Γ_3	Sat. IV. γ_4	Sat. IV. Γ_4
Jan. 3	0·0113	285·3	0·4928	280·81	0·1401	248·79	0·3185	331·19
Mar. 3	·0112	283·5	·4927	278·90	·1391	248·42	·3178	331·27
May 2	·0110	281·7	·4927	276·99	·1381	248·03	·3171	331·35
July 1	·0109	279·7	·4926	275·07	·1372	247·62	·3164	331·42
Aug. 30	·0108	277·6	·4925	273·15	·1364	247·21	·3156	331·46
Oct. 29	0·0107	275·5	0·4924	271·23	0·1356	246·79	0·3147	331·48

The following is a list of Greenwich mean times, when the zero meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc.

	I. (878°·25)	II. (870°·27)		I. (878°·25)	II. (870°·27)
1887.	h m	h m	1888.	h m	h m
Dec. 26	20 17·4	19 7·6	Jan. 20	20 28·0	14 52·8
27	15 58·1	14 59·2	21	16 8·7	20 40·0
28	21 29·2	20 46·5	22	21 39·6	16 31·4
29	17 9·9	16 38·0	23	17 20·3	22 18·6
30	22 40·9	22 25·3	24	22 51·2	18 10·1
31	18 21·6	18 16·8	25	18 31·8	14 1·5
1888.			26	14 12·4	19 48·7
Jan. 1	14 2·3	14 8·4	27	19 43·4	15 40·1
2	19 33·4	19 55·6	28	15 24·0	21 27·3
3	15 14·1	15 47·2	29	20 54·9	17 18·7
4	20 45·1	21 34·4	30	16 35·5	23 5·9
5	16 25·8	17 25·9	31	22 6·4	18 57·3
6	21 56·8	23 13·2	Feb. 1	17 47·0	14 48·8
7	17 37·5	19 4·7	2	13 27·6	20 35·9
8	23 8·5	14 56·2	3	18 58·5	16 27·3
9	18 49·2	20 43·5	4	14 39·1	22 14·4
10	14 29·9	16 35·0	5	20 10·0	18 5·9
11	20 0·9	22 22·2	6	15 50·6	13 57·3
12	15 41·5	18 13·7	7	21 21·5	19 44·4
13	21 12·5	14 5·2	8	17 2·0	15 35·8
14	16 53·2	19 52·4	9	12 42·6	11 27·2
15	22 24·2	15 43·9		22 32·9	21 22·9
16	18 4·8	21 31·1	10	18 13·5	17 14·3
17	13 45·5	17 22·6	11	13 54·0	13 5·7
18	19 16·4	23 9·8		23 44·3	23 1·4
19	14 57·1	19 1·3	12	19 24·9	18 52·8

1888.	I. (878°·25) h m	II. (870°·27) h m
Feb. 13	15 5·4	14 44·2
14	10 46·0	10 35·6
	20 36·3	20 31·3
15	16 16·8	16 22·6
16	11 57·4	12 14·0
	21 47·7	22 9·7
17	17 28·2	18 1·1
18	13 8·8	13 52·5
	22 59·0	23 48·1
19	18 39·6	19 39·5
20	14 20·1	15 30·9
21	10 0·7	11 22·2
	19 50·9	21 17·9
22	15 31·5	17 9·3
23	11 12·0	13 0 6
	21 2·2	22 56·3
24	16 42·8	18 47·6
25	12 23·3	14 39·0
26	8 3·8	10 30·3
	17 54·1	20 26·0
27	13 34·6	16 17·4
28	9 15·1	12 8 7
	19 5·4	22 4·4
29	14 45·9	17 55·7
Mar. 1	10 26·4	13 47·0
	20 16·6	23 42·7
2	15 57·1	19 34·0
3	21 27·9	15 25·4
4	17 8·4	21 12·3
5	12 48·9	17 3·7
6	8 29·4	12 55·0
	18 19·6	22 50·6
7	14 0·1	8 46·3
	23 50·3	18 41·9
8	19 30·8	14 33·2
9	15 11·3	20 20·2
10	20 42·0	16 11·5
11	16 22·5	21 58·4

1888.	I. (878°·25) h m	II. (870°·27) h m
Mar. 12	12 2·9	7 54·1
	21 53·2	17 49·7
13	17 33·6	13 41·0
14	13 14·1	19 28·0
15	18 44·8	15 19·2
16	14 25·3	21 6·2
17	10 5·7	7 1·8
	19 55·9	16 57·4
18	15 36·4	12 48·7
19	11 16·8	8 40·0
	21 7·0	18 35·6
20	16 47·5	14 26·9
21	12 27·9	10 18·1
	22 18 1	20 13·8
22	8 8·4	6 9·4
	17 58·6	16 5·0
23	13 39·0	11 56·3
	23 29·2	21 51·9
24	9 19·4	7 47·5
	19 9·7	17 43·2
25	14 50·1	13 34·4
26	10 30·5	9 25·7
	20 20·7	19 21·3
27	16 1·1	15 12·5
28	11 41·6	11 3·8
	21 31·8	20 59·4
29	17 12·2	16 50·6
30	12 52·6	12 41·9
	22 42·8	22 37·5
31	8 33·0	8 33·1
	18 23·2	18 28·7
Apr. 1	14 3·6	14 20·0
2	9 44·0	10 11·2
	19 34·2	20 6·8
3	15 14·6	15 58·0
4	10 55·0	11 49·3
	20 45·2	21 44·9
5	16 25·6	17 36·1

1888.	I. (878°·25) h m	II. (870°·27) h m	1888.	I. (878°·25) h m	II. (870°·27) m
Apr. 6	12 6·0	13 27·3	Apr. 29	10 56·3	7 25·1
	21 56·2	23 22·9		20 46·5	17 20·6
7	7 46·4	9 18·5	30	6 36·7	13 11·8
	17 36·6	19 14·1		16 26·9	23 7·4
8	13 17·0	15 5·3	May 1	12 7·2	9 3·0
9	8 57·4	10 56·6		21 57·4	18 58·6
	18 47·6	20 52·2	2	7 47·6	14 49·7
10	14 28·0	16 43·4		17 37·7	24 45·3
11	10 8·4	12 34·6	3	13 18·1	10 40·9
	19 58·5	22 30·2		23 8·3	20 36·5
12	15 38·9	18 21·4	4	8 58·4	6 32·1
13	11 19·3	14 12·6		18 48·6	16 27·7
14	6 59·7	10 3·8	5	14 29·0	12 18·8
	16 49·9	19 59·4	6	10 9·3	8 10·0
15	12 30·2	15 50·6		19 59·5	18 5·6
16	8 10·6	11 41·8	7	15 39·8	13 56·8
	18 0·8	21 37·4	8	11 20·2	9 47·9
17	13 41·2	17 28·5		21 10·3	19 43·5
18	9 21·5	13 19·7	9	16 50·7	15 34·7
	19 11·7	23 15·3	10	12 31·0	11 25·8
19	14 52·1	19 6·5		22 21·2	21 21·4
20	10 32·4	14 57·7	11	8 11·4	7 17·0
	20 22·6	24 53·3		18 1·5	17 12·6
21	6 12·8	10 48·9	12	13 41·9	13 3·7
	16 3·0	20 44·5	13	9 22·2	8 54·9
22	11 43·3	6 40·0		19 12·4	18 50·5
	21 33·5	16 35·6	14	14 52·7	14 41·7
23	7 23·7	12 26·8	15	10 33·1	10 32·8
	17 13·9	22 22·4		20 23·3	20 28·4
24	12 54·2	8 18·0	16	6 13·4	6 24·0
	22 44·4	18 13·6		16 3·6	16 19·6
25	8 34·6	14 4·8	17	11 44·0	12 10·8
	18 24·8	24 0·4		21 34·1	22 6·4
26	14 5·1	9 55·9	18	7 24·3	8 1·9
	23 55·3	19 51·5		17 14·5	17 57·3
27	9 45·5	5 47·1	19	12 54·8	13 47·7
	19 35·6	15 42·7	20	8 35·2	9 39·9
28	5 25·8	11 33·9		18 25·4	19 35·5
	15 16·0	21 29·5	21	14 5·7	15 26·6

1888.	I. (878°·25) h m	II. (870°·27) h m
May 22	9 46·1	11 17·8
	19 36·3	21 13·4
23	5 26·5	7 9·0
	15 16·6	17 4·6
24	10 57·0	12 55·8
	20 47·2	22 51·4
25	6 37·4	8 47·0
	16 27·5	18 42·6
26	12 7·9	14 33·7
27	7 48·3	10 24·9
	17 38·4	20 20·5
28	13 18·8	16 11·7
29	8 59·2	12 2·9
	18 49·4	21 58·5
30	4 39·6	7 54·1
	14 29·8	17 49·7
31	10 0·1	13 40 9
June 1	5 50·5	9 32·1
	15 40·7	19 27·7
2	11 21·1	5 23·3
	21 11·3	15 18·9
3	7 1·5	11 10·2
	16 51·7	21 5·8
4	12 32·1	7 1·4
	22 22·3	16 57·0
5	8 12·5	12 48·2
	18 2·7	22 43·8
6	13 43·1	8 39·4
7	9 23·5	4 30·7
	19 13·7	14 26·3
8	5 3·9	10 17·5
	14 54·1	20 13·2
9	10 34·6	6 8·8
	20 24·8	16 4·4
10	6 15·0	11 55·6
	16 5·2	21 51·3
11	11 45·6	7 46·9
	21 35·8	17 42·5
12	7 26·1	3 38·2

1888.	I. (878°·25) h m	II. (870°·27) h m
June 12	17 16·3	13 33·8
13	3 6·5	9 25·0
	12 56·7	19 20·7
14	8 37·2	5 16·3
	18 27·4	15 11·9
15	4 17·6	11 3·2
	14 7·8	20 58·8
16	9 48·3	6 54·5
	19 38·5	16 50·1
17	5 28·7	2 45·7
	15 19 0	12 41·4
18	10 59·4	8 32·7
	20 49·6	18 28·3
19	6 39·9	4 23·9
	16 30·1	14 19·6
20	12 10·6	10 10·9
21	7 51·1	6 2·2
	17 41·3	15 57·8
22	13 21·8	11 49·1
23	9 2·3	7 40·4
	18 52·5	17 36·1
24	4 42·7	3 31 8
	14 33·0	13 27·4
25	10 13·5	9 18·7
26	5 54·0	5 10·1
	15 44 2	15 5·7
27	11 24·7	10 57·0
28	7 5·2	6 48·4
	16 55·5	16 44·0
29	12 36 0	12 35·4
30	8 16·5	8 26·7
	18 6·8	18 22·4
July 1	3 57·1	4 18·1
	13 47·3	14 13·7
2	9 27·8	10 5·1
3	5 8·4	5 56·5
	14 58·6	15 52·1
4	10 39·2	11 43·5
5	6 19·7	7 34·9

1888.	I. (878°·25) h m	II. (870°·27) h m
July 5	16 10·0	17 30·5
6	11 50·5	13 21·9
7	7 31·1	9 13·3
8	3 11·7	5 4·7
	13 1·9	15 0 4
9	8 42·5	10 51·8
10	4 23·1	6 43·2
	14 13·4	16 38·9
11	9 53·9	12 30 3
12	15 24·8	8 21·7
13	11 5·4	14 8·8
14	6 46·0	10 0·2
15	12 16·9	15 47·3
16	7 57·5	11 38·7
17	13 28·4	7 30·2
18	9 9·0	13 17·3
19	14 39·9	9 8·8
20	10 20·5	14 55·9
21	6 1·1	10 47·4
22	11 32·1	6 38·8
23	7 12·7	12 26·0
24	12 43·7	8 17·5
25	8 24·3	14 4·7
26	13 55·3	9 56·2
27	9 35·9	5 47·6
28	5 16·6	11 34 9
29	10 47·6	7 26·3
30	6 28·2	13 13·6
31	11 59·2	9 5·1
Aug. 1	7 39·9	14 52·3
2	13 10·9	10 43·8
3	8 51·6	6 35·3
4	14 22·6	12 22·6
5	9 3·3	8 14 1
6	5 44·0	14 1·4
7	11 15·0	9 52·9
8	6 55·7	5 44·4
9	12 26·8	11 31·7
10	8 7·5	7 23·2

1885.	I. (878° 25) h m	II. (870°·27) h m
Aug. 11	13 38·6	13 10·6
12	9 19·3	9 2·1
13	5 0·0	4 53·6
14	10 31·1	10 41·0
15	6 11·8	6 32·5
16	11 42·9	12 19·9
17	7 23·6	8 11·4
18	12 54·7	13 58·8
19	8 35·5	9 50·3
20	4 16·2	5 41·9
21	9 47·3	11 29·3
22	5 28·1	7 20·8
23	10 59·2	13 8·2
24	6 40·0	8 59·8
25	12 11·1	4 51·4
26	7 51·9	10 38·8
27	13 23·0	6 30·4
28	9 3·8	12 17·7
29	4 44·5	8 9·3
30	10 15·7	4 0·9
31	5 56·5	9 48·3
Sept. 1	11 27·6	5 39·9
2	7 8·4	11 27·4
3	12 39·6	7 19·0
4	8 20·4	13 6·4
5	13 51·5	8 58·0
6	9 32·3	4 49·6
7	5 13·1	10 37·1
8	10 44·3	6 28·7
9	6 25·1	12 16·1
10	11 56·3	8 7·7
11	7 37·1	13 55·2
12	13 8·3	9 46·8
13	8 49·1	5 38·5
14	4 29·9	11 25·9
15	10 1·1	7 17·6
16	5 42·0	13 5·0
17	11 13·2	8 56·7
18	6 54·0	4 48·3

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. DECEMBER 9, 1887. No. 2

J. W. L. GLAISHER, M.A., Sc.D., President, in the Chair.

John Whitehouse Frederick Allnutt, B.A., 12 Chapel Row, Portsea;

Gainsford Bruce, Q.C., Yewhurst, Bromley, Kent;

Major Somerset H. Maxwell, Arley Cottage, Mount Nugent, Co. Cavan, Ireland; and

The Rev. Samuel Hickling Parkes, B.A., Swinton Industrial School, Manchester,

were balloted for and duly elected Fellows of the Society.

The Numerical Lunar Theory. By Sir G. B. Airy, K.C.B.

(*Extract from a letter to the Secretary.*)

In my "Numerical Lunar Theory," I pointed out certain discordances, the origin of which I could not trace, and which caused me great anxiety.

I have now, as I believe, discovered the source of error. In the operations of page 11, I have not carried the approximation sufficiently far. I ought to have included the eccentricities, especially that of the Terrestro-Lunar orbit. The mean value of this element (known from the coarsest observations) is about $\frac{1}{18}$, and this (comparatively) large quantity receives a large multiplier, before application to the genuine Lunar Theory.

The steps which I have already taken with this object fatigue me so much that I deem it necessary to suspend my work for a time. I hope before long to take it up again.

1887, *December* 29.

On the Double Star Σ 1847. By J. E. Gore.

Assuming that the change of position in this double star is due to uniform rectilinear motion, I have computed the following formulæ :—

$$\rho^2 = 179{\cdot}56 + 0{\cdot}0111\ (t - 1705{\cdot}12)^2.$$
$$\sec\ (\theta - 204^\circ{\cdot}10) = 0{\cdot}0746\ \rho.$$

The following is a comparison between the measures and the positions computed from the above formulæ :—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1829·8	Struve	248·4	248·5	−0·1	18·73	18·76	−0·03
1844·34	Mädler	251·5	251·6	−0·1	18·22	19·86	(−1·64)
1848·4	Mitchel	253·1	252·5	+0·6	20·17	20·18	−0·01
1865·4	Dembowski	256·0	255·7	+0·3	21·67	21·56	+0·11
1878·3	Burnham	257·8	257·8	0·0	22·63	22·64	−0·01

Assuming that the brighter star is the one in motion, the proper motion is 0″·1053 per annum in the direction of position-angle 114°·1.

For rectangular coordinates we have the formulæ—

$$\rho \sin\theta = 5{\cdot}4716 + [8{\cdot}9828203]\ (t - 1705{\cdot}12);$$
$$\rho \cos\theta = 12{\cdot}232 - [8{\cdot}6334402]\ (t - 1705{\cdot}12).$$

Ephemeris for Physical Observations of Mars, 1888. By A. Marth.

Greenwich Noon. 1888.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Apparent Diameter.	q	Q	E	Log. of Light-ratio.
	°	°	°	″	″	°	°	
Jan. 31	35·08	262·21	+20·24	8·63	0·77	290·68	34·71	9·2534
Feb. 2	35·22	243·41	+20·08	8·79	0·77	290·51	34·43	9·2702
4	35·35	224·64	19·92	8·95	·77	290·33	34·13	·2873
6	35·47	205·90	19·77	9·12	·77	290·16	33·80	·3047
8	35·58	187·20	19·62	9·29	·77	289·98	33·44	·3223
10	35·68	168·53	19·48	9·47	·77	289·80	33·05	·3401
12	35·77	149·89	19·34	9·65	·76	289·63	32·62	·3582
14	35·85	131·29	19·22	9·84	·75	289·46	32·15	·3765
16	35·93	112·72	19·10	10·03	·75	289·29	31·65	·3950
18	35·99	94·20	18·99	10·23	·74	289·11	31·11	·4137
20	36·04	75·71	18·89	10·43	·72	288·94	30·53	·4325
22	36·09	57·26	18·81	10·64	·71	288·76	29·91	·4514
24	36·13	38·85	18·73	10·85	·69	288·59	29·25	·4705
26	36·16	20·49	18·67	11·07	·67	288·41	28·54	·4896
28	36·18	2·17	18·62	11·29	·65	288·23	27·79	·5087
Mar. 1	36·20	343·89	+18·59	11·51	0·63	288·05	26·99	9·5279

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Apparent Diameter.	q	Q	E	Log. of Light-ratio.
1888.	°	°	°	″	″	°	°	
Mar. 3	36·21	325·66	18·57	11·74	0·60	287·87	26·15	·5470
5	36·21	307·48	18·56	11·97	·57	287·68	25·26	·5661
7	36·20	289·34	18·57	12·20	·54	287·48	24·31	·5850
9	36·18	271·26	18·60	12·43	·51	287·28	23·31	·6037
11	36·15	253·23	18·64	12·66	·47	287·06	22·26	·6222
13	36·11	235·24	18·70	12·89	·43	286·83	20·16	·6404
15	36·07	217·31	18·77	13·12	·40	286·57	20·00	·6582
17	36·01	199·43	18·86	13·35	·36	286·28	18·79	·6755
19	35·95	181·60	18·97	13·57	·32	285·95	17·53	·6922
21	35·87	163·82	19·09	13·79	·27	285·57	16·21	·7083
23	35·78	146·09	19·23	14·00	·23	285·11	14·85	·7237
25	35·68	128·40	19·38	14·20	·19	284·54	13·44	·7384
27	35·57	110·76	19·55	14·40	·16	283·83	11·99	·7522
29	35·45	93·16	19·73	14·58	·12	282·89	10·50	·7650
31	35·32	75·59	19·92	14·74	·09	281·60	8·97	·7769
Apr. 2	35·17	58·06	+20·12	14·90	0·06	279·73	7·41	9·7877
4	35·01	40·56	20·33	15·03	·04	276·8	5·83	·7973
6	34·84	23·09	20·55	15·15	·02	271·6	4·25	·8057
8	34·66	5·63	20·77	15·25	·01	260·2	2·72	·8128
10	34·47	348·19	20·99	15·34	·00	226·6	1·54	·8186
12	34·27	330·76	21·22	15·40	·00	164·1	1·71	·8231
14	34·06	313·34	21·45	15·44	·01	137·5	3·05	·8262
16	33·85	295·91	21·68	15·46	·03	128·0	4·62	·8280
18	33·63	278·47	21·91	15·45	·05	123·4	6·26	·8284
20	33·42	261·01	22·13	15·43	·07	120·71	7·90	·8275
22	33·20	243·53	22·34	15·39	·11	118·99	9·53	·8254
24	32·99	226·02	22·55	15·33	·15	117·79	11·15	·8220
26	32·78	208·48	22·75	15·25	·19	116·91	12·75	·8174
28	32·58	190·90	22·95	15·16	·24	116·24	14·31	·8118
30	32·39	173·28	23·14	15·05	·29	115·72	15·84	·8051
May 2	32·22	155·61	+23·31	14·92	0·34	115·30	17·33	9·7974
4	32·05	137·89	23·48	14·79	·39	114·95	18·78	·7888
6	31·90	120·13	23·64	14·64	·45	114·66	20·18	·7795
8	31·77	102·31	23·79	14·48	·50	114·42	21·54	·7694
10	31·65	84·43	23·93	14·31	·56	114·21	22·84	·7586
12	31·55	66·50	24·06	14·14	·62	114·03	24·10	·7472
14	31·47	48·50	24·18	13·96	·67	113·88	25·30	·7354
16	31·41	30·45	24·29	13·77	·72	113·74	26·46	·7231

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre	Areographical Latit. of Disc.	Apparent Diameter.	q	Q	E	Log. of Light-ratio.
1888.	°	°	°	″	″	°	°	
May 18	31·37	12·34	24·39	13·58	0·77	113·62	27·56	·7105
20	31·35	354·17	24·48	13·39	·82	113·51	28·61	·6976
22	31·35	335·94	24·56	13·20	·86	113·41	29·62	·6844
24	31·37	317·65	24·63	13·01	·90	113·32	30·57	·6711
26	31·41	299·31	24·69	12·82	·94	113·24	31·48	·6577
28	31·47	280·92	24·74	12·63	0·98	113·17	32·34	·6442
30	31·55	262·47	24·79	12·44	1·01	113·10	33·16	·6307
June 1	31·64	243·97	+24·82	12·25	1·04	113·03	33·93	9·6171
3	31·75	225·42	24·85	12·07	1·07	112·96	34·66	·6036
5	31·88	206·82	24·86	11·89	1·09	112·89	35·35	·5902
7	32·02	188·18	24·87	11·71	1·12	112·84	36·00	·5768
9	32·17	169·49	24·86	11·53	1·14	112·78	36·61	·5635
11	32·34	150·76	24·85	11·36	1·16	112·72	37·19	·5504
13	32·52	131·99	24·83	11·19	1·17	112·66	37·73	·5374
15	32·71	113·17	24·79	11·02	1·18	112·60	38·24	·5246
17	32·91	94·32	24·75	10·86	1·19	112·54	38·72	·5120
19	33·12	75·43	24·69	10·70	1·20	112·47	39·16	·4995
21	33·34	56·51	24·63	10·55	1·21	112·40	39·57	·4873
23	33·56	37·55	24·55	10·40	1·21	112·33	39·96	·4753
25	33·79	18·57	24·47	10·25	1·22	112·25	40·32	·4635
27	34·02	359·55	24·37	10·11	1·22	112·17	40·65	·4519
29	34·25	340·50	24·26	9·97	1·22	112·09	40·96	·4405
July 1	34·49	321·43	+24·14	9·84	1·22	112·00	41·24	9·4293
3	34·72	302·33	24·01	9·71	1·22	111·90	41·50	·4183
5	34·96	283·21	23·87	9·58	1·22	111·80	41·75	·4076
7	35·20	264·06	23·71	9·45	1·21	111·69	41·97	·3971
9	35·43	244·89	23·55	9·33	1·21	111·57	42·17	·3867
11	35·66	225·70	23·37	9·21	1·20	111·45	42·35	·3766
13	35·89	206·48	23·18	9·10	1·20	111·32	42·52	·3668
15	36·11	187·25	22·98	8·99	1·19	111·18	42·66	·3571
17	36·33	168·00	22·76	8·88	1·18	111·04	42·79	·3477
19	36·53	148·74	22·53	8·77	1·17	110·88	42·90	·3384
21	36·73	129·46	22·29	8·67	1·17	110·72	43·00	·3294
23	36·92	110·16	22·04	8·57	1·16	110·55	43·09	·3206
25	37·10	90·85	21·77	8·47	1·15	110·37	43·16	·3120
27	37·27	71·53	21·50	8·38	1·14	110·17	43·22	·3036
29	37·43	52·20	21·21	8·29	1·13	109·97	43·26	·2953
31	37·58	32·85	20·91	8·20	1·12	109·76	43·29	·2872
Aug. 2	37·71	13·49	+20·59	8·11	1·10	109·54	43·32	9·2793

Q denotes the position-angle and q the amount of the greatest defect of illumination; E the areocentric angle between Earth and Sun. The last column gives the logarithm of the ratio of the apparent brightness of *Mars* to that at mean opposition, the diminution of brightness due to the phase being assumed to depend simply on the proportion of the unilluminated portion to the whole of the disc.

The data of the ephemeris are to be interpolated directly for the times for which they are required, the equation of light having already been taken into account. The differences of successive values of the areographical longitude of the centre amount to one rotation and some 340 degrees, so that the greatest difference, April 12 to 14, is 702°·58, and the smallest, July 31 to August 2, 700°·64, which must be borne in mind in interpolating.

The ephemeris is founded upon the same elements as that for 1886 in vol. xlvi.

The adopted zero-meridian will be apparently directed to the Earth or will pass the centre of the disc of *Mars* at the following Greenwich mean times:—

1888.	h	m	1888.	h	m	1888.	h	m
Jan. 31	6	41·7	Feb. 22	20	42·8	Mar. 16	10	22·0
Feb. 1	7	10·3	23	21	20·5	17	10	58·6
2	7	58·9	24	21	58·2	18	11	35·2
3	8	37·4	25	22	35·9	19	12	11·7
4	9	15·9	26	23	13·5	20	12	48·1
5	9	54·4	27	23	51·1	21	13	24·6
6	10	32·8	29	0	28·6	22	14	0·9
7	11	11·2	Mar. 1	1	6·1	23	14	37·2
8	11	49·6	2	1	43·5	24	15	13·5
9	12	28·0	3	2	20·9	25	15	49·7
10	13	6·3	4	2	58·2	26	16	25·9
11	13	44·5	5	3	35·5	27	17	2·0
12	14	22·7	6	4	12·8	28	17	38·1
13	15	0·9	7	4	49·9	29	18	14·1
14	15	39·1	8	5	27·0	30	18	50·1
15	16	17·2	9	6	4·1	31	19	26·1
16	16	55·3	10	6	41·1	Apr. 1	20	2·0
17	17	33·3	11	7	18·0	2	20	37·9
18	18	11·3	12	7	54·9	3	21	13·7
19	18	49·2	13	8	31·8	4	21	49·6
20	19	27·1	14	9	8·6	5	22	25·4
21	20	5·0	15	9	45·3	6	23	1·2

1888.	h	m	1888.	h	m	1888.	h	m
Apr. 7	23	36·9	May 16	22	32·2	June 24	22	43·7
9	0	12·7	17	23	9·4	25	23	22·8
10	0	48·4	18	23	46·6	27	0	1·9
11	1	24·1	20	0	23·9	28	0	41·0
12	1	59·9	21	1	1·3	29	1	20·1
13	2	35·6	22	1	38·7	30	1	59·3
14	3	11·3	23	2	16·2	July 1	2	38·5
15	3	47·0	24	2	53·8	2	3	17·7
16	4	22·7	25	3	31·4	3	3	57·0
17	4	58·5	26	4	9·1	4	4	36·2
18	5	34·2	27	4	46·9	5	5	15·5
19	6	10·0	28	5	24·7	6	5	54·9
20	6	45·8	29	6	2·5	7	6	34·2
21	7	21·6	30	6	40·4	8	7	13·6
22	7	57·5	31	7	18·4	9	7	53·0
23	8	33·4	June 1	7	56·4	10	8	32·5
24	9	9·3	2	8	34·5	11	9	11·9
25	9	45·2	3	9	12 6	12	9	51·4
26	10	21·2	4	9	50·8	13	10	30·9
27	10	57·3	5	10	29·0	14	11	10·4
28	11	33·4	6	11	7·3	15	11	50·0
29	12	9·5	7	11	45·6	16	12	29·5
30	12	45·7	8	12	24·0	17	13	9·1
May 1	13	21·9	9	13	2·4	18	13	48·7
2	13	58·2	10	13	40·8	19	14	28·3
3	14	34·5	11	14	19·3	20	15	7·9
4	15	10·9	12	14	57·9	21	15	47·5
5	15	47·3	13	15	36·5	22	16	27·2
6	16	23·8	14	16	15·2	23	17	6·9
7	17	0·4	15	16	53·9	24	17	46·6
8	17	37·0	16	17	32·6	25	18	26·3
9	18	13·7	17	18	11·4	26	19	6·0
10	18	50·4	18	18	50·2	27	19	45·7
11	19	27·2	19	19	29·0	28	20	25·4
12	20	4·1	20	20	7·9	29	21	5·2
13	20	41·0	21	20	46·8	30	21	45·0
14	21	18·0	22	21	25·7	31	22	24·8
15	21	55·1	23	22	4·7	Aug. 1	23	4·6

The chief dates connected with the astronomical seasons of *Mars* are:—

1888, Feb.	16.	Summer solstice of ♂'s northern hemisphere.
April	20.	Beginning of autumnal season of transits and eclipses of the satellites. First of about 663 transits of *Phobos* across the Sun's disc.
	23.	First of about 644 eclipses of *Phobos*.
July	6.	First of 56 transits of *Deimos*.
	8.	First of 54 eclipses of *Deimos*.
Aug.	15.	Autumnal equinox.
Sept.	14.	Last of 54 eclipses of *Deimos*.
	16.	Last of 56 transits of *Deimos*.
Nov.	14.	Last eclipse of *Phobos*.
	17.	Last transit of *Phobos*. End of autumnal season of transits and eclipses.
1889, Jan.	8.	Winter solstice of ♂'s northern hemisphere.
Feb.	25.	Beginning of vernal season of transits and eclipses. First of about 740 transits of *Phobos*.
	28.	First of about 722 eclipses of *Phobos*.
May	5.	First of 64 transits of *Deimos*.
	7.	First of 62 eclipses of *Deimos*.
June	7.	Vernal equinox of ♂'s northern hemisphere.
July	23.	Last of 62 eclipses of *Deimos*.
	25.	Last of 64 transits of *Deimos*.
Oct.	16.	Last eclipse of *Phobos*.
	19.	Last transit of *Phobos*. End of vernal season of transits and eclipses.
1890, Jan.	2.	Summer solstice of ♂'s northern hemisphere.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. JANUARY 13, 1888. No. 3

J. W. L. GLAISHER, Sc.D., F.R.S., President, in the Chair.

Edward E. Barnard, M.A., Lick Observatory, Mount Hamilton, California, U.S.A.;
William R. Brooks, Red House Observatory, Phelps, N.Y., U.S.A.;
Captain Leonard Darwin, R.E., 18 Wetherby Place, South Kensington, S.W.;
James Gill, 2 Beech Mount, Fairfield, Liverpool;
William B. Hutchinson, The Observatory, Liversedge, Yorkshire;
George James Jacobs, Lansdowne, Guildford, Surrey;
Rev. Joseph Walshe, St. Edward's College, Liverpool; and
Francis James Wardale, 1 Whitehall Place, S.W.,

were balloted for and duly elected Fellows of the Society.

Request to Observers of Variable Stars. By Professor J. A. C. Oudemans.

(*Extract from a letter to the Secretary.*)

Being occupied in deducing new elements of *Algol* for the second volume of Kaiser's "Sterrenhemel," I am much disappointed by the fact that observers of variable stars do not hasten to publish their observations. You would oblige me very much by communicating my general request that observers of the minima of *Algol* would send me their results, especially those obtained since 1883.

Utrecht: 1888, *January* 11.

Observations of the Moon, made at the Radcliffe Observatory, Oxford, during the year 1887, *and a comparison of the Results with the Tabular Places from Hansen's Lunar Tables.* By E. J. Stone, M.A., F.R.S.

The present paper contains the Right Ascensions and North Polar Distances of the Moon, as deduced from the observations made at the Radcliffe Observatory during the year 1887. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions :—

(1) That the mean times, found in the usual way from the sidereal times at mean noon given in the *Nautical Almanac*, were *not* changed in 1864 by the adoption of a different unit of time.

(2) That the mean times *were* changed in 1864 by the adoption of a different unit of time, in accordance with the views which I have explained in papers already communicated to the Society.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations we are again indebted to the places published in the *Connaissance des Temps*.

TABLE I.

Radcliffe Observations of the Moon, 1887.

Day, 1887.		Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	Seconds of Hansen's R.A.	Hansen *minus* Observed. Uncorrected for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. Corrected for Error in Time.	Observed N.P.D.	Seconds of Hansen's N.P.D.	Hansen *minus* Observed. Uncorrected for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. Corrected for Error in Time.
		s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Jan.	4	34·19	W.	2 36 52·76	53·55	+0·79	−1·16	−0·37	79 47 35·98	33·67	−2·31	+5·02	+2·71
	5	34·20	F. B.	3 28 43·54	44·41	+0·87	−1·23	−0·36	76 22 45·16	41·91	−3·25	+4·34	+1·09
	6	34·20	W.	4 23 45·62	46·36	+0·74	−1·30	−0·56	73 34 13·55	11·57	−1·98	+3·33	+1·35
	12	34·22	W.	10 32 26·16	27·58	+1·42	−1·36	+0·06	80 4 7·22	8·26	+1·04	−5·95	−4·91
	16	34·24	R.	14 17 25·80	27·93	+1·13	−1·26	−0·13	98 41 7·79	11·53	+3·74	−5·78	−2·04
	31	34·30	R.	2 16 7·06	7·60	+0·54	−1·12	−0·58	81 29 27·80	23·34	−4·46	+5·14	+0·68
Feb.	1	34·30	W.	3 5 33·72	34·35	+0·63	−1·17	−0·54	77 57 42·95	39·32	−3·63	+4·60	+0·97
	2	34·31	F. B.	3 57 40·43	41·33	+0·90	−1·24	−0·34	74 54 48·68	44·24	−4·44	+3·79	−0·65
	4	34·32	R.	5 51 35·23	35·83	+0·60	−1·38	−0·78	71 8 56·15	53·96	−2·19	+1·20	−0·99
	5	34·32	F. B.	6 53 2·65	3·49	+0·84	−1·43	−0·59	70 54 12·16	11·43	−0·73	−0·54	−1·27
	7	34·33	R.	9 0 1·13	2·16	+1·03	−1·45	−0·42	74 23 20·22	22·92	+2·70	−4·17	−1·47
	28	34·41	F. B.	2 47 5·20	5·89	+0·69	−1·13	−0·44	79 13 10·15	7·03	−3·12	+4·77	+1·65
Mar.	2	34·42	R.	4 29 42·65	43·13	+0·48	−1·25	−0·77	73 25 49·71	46·16	−3·55	+3·09	−0·46
	3	34·42	R.	5 25 8·55	9·14	+0·59	−1·31	−0·72	71 38 15·87	14·16	−1·71	+1·82	+0·11
	4	34·43	R.	6 23 24·15	24·91	+0·76	−1·37	−0·61	70 51 10·61	8·24	−2·37	+0·30	−2·07
April	7	34·56	W.	12 59 15·23	16·30	+1·07	−1·38	−0·31	92 13 40·60	45·82	+5·22	−7·21	−1·99

Day, 1887		Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	Seconds of Hansen's R.A.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.	Observed N.P.D.	Seconds of Hansen's N.P.D.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.
		s		h m s	s	s	s	s	° ′ ″	″	″	″	″
May	5	34·68	F. B.	13 28 42·40	43·31	+0·91	−1·36	−0·45	94 43 34·49	39·20	+4·71	−7·01	−2·30
	7	34·68	F. B.	15 27 57·62	58·99	+1·37	−1·40	−0·03	103 41 59·31	64·92	+5·61	−5·15	+0·46
	9	34·69	R.	17 29 28·81	30·02	+1·21	−1·40	−0·19	108 51 52·73	54·17	+1·44	−1·91	−0·47
	12	34·70	R.	20 22 11·07	12·40	+1·33	−1·25	+0·08	107 40 24·67	23·96	−0·71	+2·72	+2·01
	13	34·71	F. B.	21 14 39·38	40·93	+1·55	−1·19	+0·36	105 19 50·22	46·33	−3·89	+3·79	−0·10
June	4	34·80	R.	15 59 49·23	50·45	+1·22	−1·40	−0·18	105 30 30·36	33·10	+2·74	−4·43	−1·69
	8	34·81	F. B.	19 57 39·42	40·82	+1·40	−1·31	+0·09	108 39 53·85	53·31	−0·54	+2·15	+1·61
	9	34·82	W.	20 52 23·57	24·99	+1·42	−1·25	+0·17	106 39 49·37	47·57	−1·80	+3·41	+1·61
	10	34·82	F. B.	21 44 18·38	20·14	+1·76	−1·18	+0·58	103 52 54·63	49·23	−3·40	+4·36	+0·96
	30	34·90	R.	14 39 36·61	37·46	+0·85	−1·33	−0·48	100 11 41·85	45·76	+3·91	−6·01	−2·10
July	2	34·91	R.	16 35 35·93	37·16	+1·23	−1·38	−0·15	107 8 9·46	11·90	+2·44	−3·52	−1·08
	5	34·92	F. B.	19 32 36·92	38·48	+1·56	−1·34	+0·22	109 18 55·95	55·14	−0·81	+1·47	+0·66
	7	34·93	F. B.	21 22 21·37	22·83	+1·46	−1·23	+0·23	105 17 50·40	46·02	−4·38	+3·99	−0·39
	27	35·01	R.	14 22 49·38	50·26	+0·88	−1·32	−0·44	98 46 25·26	31·36	+6·10	−6·25	−0·15
	29	35·02	R.	16 16 34·11	35·17	+1·06	−1·35	−0·29	106 10 53·08	55·69	+2·61	−3·97	−1·36
	30	35·02	F. B.	17 14 38·08	39·44	+1·36	−1·37	−0·01	108 28 7·39	10·38	+2·99	−2·44	+0·55
Aug.	1	35·03	F. B.	19 10 42·80	43·89	+1·09	−1·34	−0·25	109 36 33·10	32·59	−0·51	+0·83	+0·32
	2	35·03	R.	20 7 2·45	3·58	+1·13	−1·30	−0·17	108 29 9·92	6·92	−3·00	+2·30	−0·70
	3	35·04	F. B.	21 1 17·31	18·67	+1·36	−1·25	+0·11	106 23 32·93	29·80	−3·13	+3·56	+0·43
	4	35·04	R.	21 53 11·14	12·25	+1·11	−1·20	−0·09	103 30 61·57	57·28	−4·29	+4·53	+0·24
	7	35·05	R.	0 17 2·73	3·96	+1·23	−1·09	+0·14	92 10 6·27	1·75	−4·52	+5·83	+1·31

Day, 1887.		Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	Seconds of Hansen's R.A.	Hansen *minus* Observed. Uncorrected for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. Corrected for Error in Time.	Observed N.P.D.	Seconds of Hansen's N.P.D.	Hansen *minus* Observed. Uncorrected for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. Corrected for Error in Time.
		s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Aug.	25	35·12	F. B.	15 59 3·71	5·08	+1·37	−1·36	+0·01	105 16 33·77	36·03	+2·26	−4·43	−2·17
	27	35·13	F. B.	17 55 7·46	8·83	+1·37	−1·36	+0·01	109 23 47·99	47·70	−0·29	−1·30	−1·59
Sept.	28	35·26	R.	22 9 17·36	18·42	+1·06	−1·17	−0·11	102 30 21·51	16·61	−4·90	+4·79	−0·11
Oct.	10	35·31	R.	8 11 2·51	3·62	+1·11	−1·38	−0·27	71 24 34·29	37·08	+2·79	−2·60	+0·19
	24	35·36	W.	21 2 17·73	18·96	+1·23	−1·25	−0·02	106 38 16·87	12·71	−4·16	+3·64	−0·52
	25	35·37	R.	21 53 33·64	34·71	+1·07	−1·19	−0·12	103 44 11·59	6·13	−5·46	+4·59	−0·87
	28	35·38	R.	0 15 46·65	47·65	+1·00	−1·09	−0·09	92 17 42·16	36·98	−5·18	+5·98	+0·80
	31	35·39	W.	2 34 23·99	24·98	+0·99	−1·13	−0·14	80 4 59·97	55·64	−4·33	+5·35	+1·02
Nov.	1	35·40	R.	3 22 43·74	44·86	+1·12	−1·17	−0·05	76 34 3·75	0·47	−3·28	+4·67	+1·39
	4	35·41	R.	5 59 2·08	2·98	+0·90	−1·30	−0·40	70 3 52·53	49·69	−2·84	+1·18	−1·66
	24	35·49	F. B.	0 0 2·06	3·14	+1·08	−1·10	−0·02	93 56 31·67	29·22	−2·45	+5·99	+3·54
	29	35·51	R.	3 55 30·82	31·67	+0·85	−1·21	−0·36	74 31 13·99	9·46	−4·53	+4·22	−0·31
Dec.	8	35·54	R.	12 14 6·89	7·90	+1·01	−1·32	−0·31	87 12 14·17	17·30	+3·13	−7·27	−4·14
	23	35·60	R.	1 13 56·56	57·44	+0·88	−1·10	−0·22	87 20 27·58	22·73	−4·85	+6·08	+1·23
	26	35·62	R.	3 35 43·63	44·28	+0·65	−1·20	−0·55	75 49 38·90	34·59	−4·31	+4·64	+0·33
	27	35·62	W.	4 26 50·45	51·37	+0·92	−1·25	−0·33	72 55 40·01	36·19	−3·82	+3·65	−0·17
	28	35·62	F. B.	5 20 27·93	28·85	+0·92	−1·31	−0·39	70 48 39·40	35·61	−3·79	+2·39	−1·40
Mean of Errors, without regard to sign						s 1·057	...	s 0·291	... ...	...	″ 3·191	...	″ 1·229
Mean Errors for Year						+ 1·057	...	−0·214					

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

TABLE II.

Radcliffe Observations of the Moon, 1887.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance, "Uncorrected" and "Corrected" for the change in Tabular Mean Time introduced in the year 1864.

Day.		Errors of Longitude (Hansen *minus* Observed).		Errors of E.N.P.D. (Hansen *minus* Observed).	
		Uncorrected.	Corrected.	Uncorrected.	Corrected.
1887 Jan.	4	+11″·85	−6″·06	+1″·43	+0″·88
	5	+13·15	−5·38	−0·03	−0·24
	6	+10·87	−8·20	−0·22	+0·02
	12	+19·88	−0·99	−6·77	−4·89
	16	+17·14	−2·50	−1·99	−1·29
Jan.	31	+9·07	−8·37	−1·56	−2·21
Feb.	1	+9·94	−7·92	−0·95	−1·25
	2	+13·72	−4·71	−1·70	−1·64
	4	+8·56	−11·08	−2·07	−1·15
	5	+11·82	−8·46	−1·78	−0·52
	7	+15·05	−6·24	−1·60	+0·30
Feb.	28	+10·67	−6·70	+0·04	−0·35
March	2	+7·40	−10·92	−3·40	−2·15
	3	+8·51	−10·26	−1·19	−0·52
	4	+10·69	−8·74	−2·81	−1·71
April	7	+16·84	−5·06	−1·37	−0·04
May	5	+14·42	−7·12	−0·66	+0·35
	7	+20·81	−0·31	+0·54	+0·55
	9	+17·26	−2·72	+0·53	−0·33
	12	+18·67	+0·65	+3·71	+2·22
	13	+22·55	+5·00	+2·97	+1·46
June	4	+17·90	−2·90	−0·84	−1·14
	8	+19·66	+0·94	+3·38	+1·83
	9	+20·11	+1·91	+3·81	+2·21
	10	+25·31	+7·65	+5·24	+3·69
June	30	+13·20	−7·42	−0·12	+0·17

Day.		Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Uncorrected.	Corrected.
1887.		″	″	″	″
July	2	+17·88	− 2·29	−0·12	−0·76
	5	+21·95	+ 2·97	+2·65	+1·14
	7	+21·42	+ 3·28	+2·32	+0·65
July	27	+14·39	− 6·25	+1·54	+1·98
	29	+15·56	− 4·37	−0·10	−0·61
	30	+19·58	+ 0·19	+1·44	+0·56
Aug.	1	+15·39	− 3·55	+1·35	−0·11
	2	+16·36	− 2·22	+0·45	−1·19
	3	+19·65	+ 1·39	+2·55	+0·86
	4	+16·69	− 1·32	+1·46	−0·22
	7	+18·80	+ 1·41	+3·19	+2·04
Aug.	25	+19·97	− 0·30	−1·76	−2·16
	27	+19·41	+ 0·14	−0·43	−0·59
Sept.	8	+16·26	− 1·47	+0·89	−0·67
Oct.	10	+16·03	− 3·71	−0·70	+1·02
Oct.	24	+18·15	− 0·13	+1·03	−0·58
	25	+16·53	− 1·35	+0·17	−1·41
	28	+15·88	− 1·56	+1·20	+0·20
	31	+15·31	− 2·29	+0·46	+0·32
Nov.	1	+16·70	− 1·06	+0·98	+1·16
	4	+12·71	− 5·65	−2·84	−1·66
Nov.	24	+15·83	− 1·69	+4·24	+3·30
	29	+13·00	− 5·04	−1·91	−1·37
Dec.	8	+15·21	− 5·94	−3·15	−1·96
Dec.	23	+14·10	− 3·53	+0·51	−0·11
	26	+10·24	− 7·88	−1·97	−1·56
	27	+13·68	− 4·66	−1·68	−0·92
	28	+13·29	− 5·42	−2·88	−1·78
Mean of Errors, without regard to sign		**...15″·649**	**4″·246**	**1″·754**	**1″·184**
Mean Errors for Year		**+15″·649**	**−3″·299**		

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 *to* 1887, *as computed from Hansen's Tables.*

"Uncorrected" and "Corrected" on and after 1864 *for the change in Tabular Mean Time, introduced in the year* 1864.

Year.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.
	"	"
1847	+ 1·07	+ 1·07
1848	+ 0·20	+ 0·20
1849	− 0·47	− 0·47
1850	− 0·28	− 0·28
1851	− 1·29	− 1·29
1852	− 0·92	− 0·92
1853	− 1·63	− 1·63
1854	− 1·68	− 1·68
1855	− 0·87	− 0·87
1856	− 0·96	− 0·96
1857	− 1·86	− 1·86
1858	− 1·98	− 1·98
1859	− 1·80	− 1·80
1860	− 2·90	− 2·90
1861	− 2·19	− 2·19
1862	− 2·83	− 2·83
1863	− 1·61	− 1·61
1864	+ 0·12	− 0·81
1865	+ 1·27	− 0·22
1866	+ 2·14	− 0·22
1867	+ 3·48	+ 0·36
1868	+ 4·12	+ 0·28
1869	+ 4·28	− 0·35
1870	+ 4·83	− 0·66
1871	+ 6·96	+ 0·44
1872	+ 7·31	+ 0·10
1873	+ 8·24	+ 0·20
1874	+ 9·29	+ 0·56
1875	+ 9·87	+ 0·36
1876	+ 9·80	− 0·51
1877	+ 9·23	− 1·90
1878	+ 8·22	− 3·60
1879*	+ 9·63	− 3 12
1880	+ 10·89	− 2·77
1881	+ 10·51	− 4·06
1882†	+ 12·68	− 2·51
1883	+ 14·71	− 1·50
1884	+ 14·65	− 1·91
1885	+ 15·14	− 1·87
1886	+ 15·34	− 2·53
1887‡	+ 15·65	− 3·30

* All to 1879, Greenwich observations.
† 1880 to 1882, Mean of Greenwich and Radcliffe.
‡ 1883 and since, Radcliffe only.

Radcliffe Observatory, Oxford:
1888, *January* 9.

Note on the Total Solar Eclipse of 1889, *January* 1.

By J. R. Hind, LL.D., F.R.S.

The belt of totality in the solar eclipse on January 1 next traverses California, where at that season favourable atmospheric conditions for observation may be anticipated with some degree of confidence.

The central line meets the American coast at Point Arena, traversing the State of California in the direction of Pilot Peak, which is also close upon the central eclipse. At Point Arena totality commences at $1^h\ 30^m\ 33^s$ local mean time, or at $1^h\ 45^m\ 13^s$ Pacific standard time, and continues $2^m\ 3^s$ according to the elements of the *Nautical Almanac*, the Sun at an altitude of 25°. At Pilot Peak totality commences at $1^h\ 45^m\ 54^s$ local mean time, or at $1^h\ 49^m\ 46^s$ Pacific standard time, and continues $1^m\ 57^s$, with the Sun at an altitude of 23°. Between these points the central eclipse crosses the track of the Central Pacific Railroad, or rather branches of that line, north of Colusa. Probably any observers proceeding from Europe for the observation of this phenomenon will not care to locate themselves east of the Sierra Nevada, the duration of totality of course diminishing with decreasing westerly longitude, and the Sun's altitude also becoming less, so that in 105° 29′ W. and 46° 39′ N., close on the central line, the total eclipse begins at $3^h\ 4^m\ 14^s$ local mean time, and continues $1^m\ 25^s$, with the Sun at an altitude of only 9°. The main line of the Central Pacific appears to be again crossed near Oreana.

At Mendocino totality commences at $1^h\ 29^m\ 47^s$ local mean time, and continues $1^m\ 45^s$. At San Francisco and its suburbs Alameda, Oakland, and Berkeley (the seat of the University of California, now presided over by our associate Prof. Holden), the eclipse, though very large, will not be total. At San Francisco the magnitude is 0·987, and it is to be regretted that the Lick Observatory on Mount Hamilton is not within the shadow; the greatest eclipse occurs there at $1^h\ 45^m$ local mean time, magnitude 0·974.

For any place near Point Arena the *Greenwich* mean time (t) of beginning and ending of totality may be found from the following expressions:—

$$\cos\omega = +125{\cdot}9912 - [2{\cdot}14556]\sin l + [1{\cdot}75929]\cos l\,.\cos(\lambda + 334^\circ\ 32'{\cdot}6)$$

$$t = 8^h\ 54^m\ 7^s{\cdot}6 \mp [1{\cdot}78807]\sin\omega + [2{\cdot}72053]\sin l - [3{\cdot}96675]\cos l\cos(\lambda + 236^\circ\ 27'{\cdot}3)$$

where l is the *geocentric* latitude of the place, λ the longitude west of Greenwich, taken *negatively*, and the quantities within the square brackets are logarithms.

The track of the central eclipse between $9^h\ 45^m$ and $10^h\ 0^m$ Greenwich mean time is as follows:—

Greenwich M.T.	Long. W.	Lat. N.	Duration of Totality on Central Line	Sun's Altitude
h m	° ′	° ′	m s	°
9 45·0	124 21·7	38 44 6	2 4·1	25·5
9 47·5	122 56·4	39 11·7	2 1·3	24·5
9 50·0	121 25·9	39 42·5	1 58·1	23·3
9 52·5	119 49·3	40 17·7	1 54·6	22·0
9 55·0	118 4·8	40 58·3	1 50·9	20·6
9 57·5	116 9·7	41 45·6	1 46·9	19·0
10 0·0	114 0·5	42 41·2	1 42·7	17·1

The Opposition of Sappho (80) *in* 1888.

By Robert Bryant, B.A., B.Sc.

This planet comes into opposition in longitude about 1888, April 12. The usual opportunity will then be afforded for obtaining the observations requisite for the correction of the elements of the planet's orbit. And that these observations should be made seems highly desirable for two reasons. Firstly, the observations of this planet between the years 1872 and 1882 were very few, so that this somewhat long neglect of the planet strengthens its claim for re-observation; and secondly, in August and September 1889 the planet makes one of those near approaches to the Earth which, on account of the eccentricity of its orbit and the near commensurability of its period with that of the Earth, occur every seven years.

For this purpose the following ephemeris for Greenwich midnight has been prepared, to which is added a suitable list of comparison stars, of which observers are requested to make use.

Observers using the transit instrument for observation of the planet may also be able to observe the corresponding comparison star.

☿ in Longitude, 1888, April 11·7.

Magnitude 11.

Greenwich Midnight. 1888.	Right Ascension.	Declination.	Log Δ.	Aberration.	Comp. Star.
	h m s	° ′ ″		m s	
Mar. 27	13 34 19·00	−14 26 34·7	0·23956	14 24	21
28	33 30·18	−14 19 51·0			20
29	32 40·47	−14 12 58·3	0·23677	14 19	20
30	31 49·93	−14 5 56·5			19
31	30 58·61	−13 58 45·9	0·23425	14 14	19
April 1	30 6·57	−13 51 26·9			18

Greenwich. Midnight. 1888.	Right Ascension. h m s	Declination. ° ′ ″	Log Δ.	Aberration. m s	Comp. Star.
April 2	13 29 13·87	−13 43 59·9	0·23198	14 10	17
3	28 20·56	−13 36 25·1			17
4	27 26·71	−13 28 42·9	0·23001	14 5	14
5	26 32·38	−13 20 53·7			14
6	25 37·63	−13 12 57·8	0·22830	14 2	16
7	24 42·53	−13 4 55·7			16
8	23 47·13	−12 56 47·8	0·22688	13 59	15
9	22 51·51	−12 48 34·5			15
10	21 55·72	−12 40 16·3	0·22577	13 57	13
11	20 59·85	−12 31 53·6			13
12	20 3·96	−12 23 27·0	0·22494	13 56	12
13	19 8·12	−12 14 57·0			11
14	18 12·40	−12 6 24·0	0·22441	13 55	10, 11
15	17 16·87	−11 57 48·6			10
16	16 21·58	−11 49 11·2	0·22419	13 54	9
17	15 26·61	−11 40 32·5			9
18	14 32·01	−11 31 52·9	0·22426	13 54	8
19	13 37·85	−11 23 12·9			8
20	12 44·18	−11 14 33·0	0·22462	13 55	6
21	11 51·07	−11 5 53·7			6
22	10 58·57	−10 57 15·5	0·22528	13 57	7
23	10 6·75	−10 48 28·9			7
24	9 15·63	−10 40 4·3	0·22622	13 58	5
25	8 25·30	−10 31 32·4			4, 5
26	7 35·78	−10 23 3·4	0·22743	14 0	4
27	6 47·14	−10 14 38·0			2
28	5 59·41	−10 6 16·4	0·22492	14 3	1, 2
29	5 12·66	− 9 57 59·1			3
30	13 4 26·91	− 9 49 46·6	0·23066	14 7	3

Comparison Stars.

No.	Mag.	R.A. 1888·0. h m s	δ 1888·0. ° ′ ″	Authority.	Date for use.
1	5·8	13 2 1·40	−10 8 24·0	B.A. Cat. Lamont	Apr. 28
2	8·3	4 39·95	−10 13 0·7	Santini	27, 28
3	8·0	5 28	− 9 54·7	D.M. −9° 3641	29, 30
4	9·6	8 52·13	−10 25 18·4	Lamont	25, 26
5	8·7	10 3·98	−10 38 50·2	Paris, 1882	24, 25
6	8·7	10 56·99	−11 10 39·0	Weisse, Santini	20, 21

No.	Mag.	R.A. 1888·0 h m s	δ 1888·0 ° ′ ″	Authority.	Date for use.
7	6·7	13 11 28·86	−10 53 35·0	Gould's Cat.	22, 23
8	7·5	12 56·35	−11 25 30·0	Weisse, Santini	18, 19
9	9·2	14 28	−11 46·7	D.M. −11° 3493	16, 17
10	7	16 12·96	−11 59 32·0	Gould, Paris, 1870	14, 15
11	5	20 48·35	−12 7 27·8	Gould, Yarn. (*i Virginis*)	13, 14
12	9·0	21 32·25	−12 23 25·5	Santini, Lamont	12
13	9·5	21 35	−12 35·5	D.M. −12° 3819	10, 11
14	8·7	24 0·46	−13 25 21·0	Weisse, Santini, Lamont	4. 5
15	7	25 16·70	−12 52 15·0	Gould, Paris, 1870	8, 9
16	9·7	25 47	−13 8·6	D.M. −12° 3834	6, 7
17	8·9	27 26·12	−13 40 13·5	Weisse, Santini	2, 3
18	9·5	31 26	−13 51·6	D.M. −13° 3733	1
19	7·8	32 1·61	−14 1 16·2	Paris, 1855, 1879	Mar. 30. 31
20	9·2	32 26	−14 16·6	D.M. −14° 3763	28, 29
21	8	13 36 52·78	−14 28 7·8	Paris, 1882, 1883	27

Precession for 1888·0 *of the above stars.*

No.	Prec. R.A. s	Prec. δ ″	No.	Prec. R.A. s	Prec. δ ″
1	+3·135	−19·32	12	+3·174	−18·79
2	+3·139	−19·26	13	+3·175	−18·79
3	+3·137	−19·24	14	+3·186	−18·72
4	+3·144	−19·15	15	+3·182	−18·68
5	+3·147	−19·12	16	+3·185	−18·66
6	+3·152	−19·10	17	+3 192	−18·61
7	+3·150	−19·08	18	+3·199	−18·47
8	+3·156	−19·04	19	+3·202	−18·46
9	+3·160	−19 00	20	+3·205	−18·44
10	+3·164	−18·95	21	+3·213	−18·29
11	+3·170	−18·82			

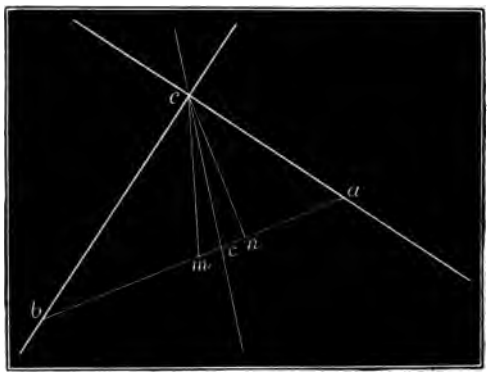
Observers are requested to publish their observations as early as possible, so that the final corrections of the assumed elements of the planet's orbit may be obtained.

On the Cross Reticule. By G. L. Tupman.

Of the various devices for utilising the diurnal motion of the Earth for micrometric measurements, without the aid of artificial light, a reticule of two straight, stout wires or bars crossing each other at right angles at the centre of the field,

and *admitting of being accurately oriented*, offers the greatest convenience in practice.

The simple theory of such a reticule may be thus stated :—



Let *ca*, *cb* be two wires inclined to one another at any angle 2γ, forming a simple cross reticule, of which *cx* is the axis lying nearest to an hour-circle, *cn*; let this axis make any angle θ (less than γ) with the hour-circle; let *ab*, perpendicular to *cn*, be the path of a star near the meridian across the reticule, and *m* the middle point of *ab*. Then $acx = \gamma$, $ncx = \theta$, and $mcx = y$ suppose.

The mean of the recorded times of transit at *a* and *b* will be the time of passing the point *m*; but in order to compare two stars in R.A. their transits over the hour-circle *cn* must be compared. Hence the time of describing the distance *nm* must be applied to the mean of the observed times in order to know the instant of passing the point *n*.

Now

$$\sin y = \tan \theta \,.\, \tan^2 \gamma$$

$$cn = \frac{\frac{1}{2} ab \,.\, \cos(\gamma + \theta) \cos(\gamma - \theta)}{\sin(\gamma + y)},$$

and

$$mn = cn \,.\, \tan(y + \theta).$$

If now $\gamma = 45°$ and θ be small, we shall have

$$y = \theta$$

$$cn = \tfrac{1}{2} ab$$

$$mn = \tfrac{1}{2} ab \sin 2\theta.$$

These simple expressions show the advantage of using wires at right angles, each inclined *nearly* 45° to the hour-circle, and by-and-by we shall see that some of the small corrections are thereby reduced to their simplest form.

A great advantage of this form of reticule is that the centre

portion of the field of view, where definition is best, is most used; and the wires being radial are in the best possible position for being sharply defined by the eyepiece.

The bars of my reticule are of watch-spring one-third of a millimeter broad. I had no difficulty in selecting two pieces with perfectly straight edges. The circular aperture of the diaphragm is one inch, over which the bars are held in position by screws. The eyepiece is of the Ramsden form, about 1¼ inch focus, the lenses of which are placed a little nearer together than is usual, thus enlarging the available field.

If it were intended to use such a reticule without a position-circle, it would be necessary to place a fibre of silk between the bars and bisecting, as nearly as possible, one pair of the angles. The exact angles which the bars make with the fibre would then have to be carefully determined by observations of selected stars.

The sliding tube which carries the reticule must be fitted with a ring-clamp, on which is a stud or projection fitting cleanly into a corresponding notch in the revolving central portion of the position-circle, so that the connection between the bars and the verniers is rigid, and the zero preserved when the eyepiece is withdrawn.

As soon as the Sun has set,* the telescope should be pointed on rather a bright star near the equator with a small easterly hour-angle. A few minutes will then suffice to adjust the reticule exactly to focus and approximately oriented when the position-circle has any given reading. The ring-clamp can then be tightened, which will permanently fix the bars in focus and in relation to the verniers of the position-circle.

One bar being approximately parallel to the direction of the diurnal motion, bring the star to the centre of the field, and, by means of the slow motion in declination, bisect it with an edge of the said bar, then quickly shifting the telescope so that the star is on the extreme preceding side of the field, turn the position-circle centre until the star is again bisected by the same edge. Allow the star to traverse the field and alter the position of the bar until the star remains bisected along the entire length of the bar.† Then read both verniers of the position-circle.

In this manner the readings of the position-circle are obtained when both edges of both bars are truly oriented. It will be found easy to have a discordance of 3′ in any one reading, hence this must be done often to ensure obtaining the angle between the bars with the accuracy desirable, say 1′.

At Harrow, with the telescope on the *East* side of the pillar, the mean reading for bar A was 0° 2′·8; for bar B 89° 51′·8.

* If this be done at night the field of view must be illuminated; but these observations can be made exceedingly well by using the trapezium in the Great Nebula of *Orion*, without artificial illumination.

† If the polar axis of the equatorial be well adjusted, these observations can be more quickly made by swinging backwards and forwards in R.A. with the slow motion.

The position-circle being graduated in the order N*f*S*p*, when its setting is 44° 57′·3 (the zero of orientation) the axis of the larger angle, 90° 11′, will coincide with the hour-circle—in other words, the reticule will be correctly oriented with its larger angle placed for measuring differences of declination.

The zero of orientation thus obtained cannot be used with any other pointing of the telescope unless the observer has satisfied himself that flexure produces no sensible effect.

When the instrument used above was reversed to the *West* side of the pillar, it was found that the bar A was correctly oriented when the reading was 0° 14′·5, repeated reversals giving the same result. This indicates a coefficient of flexure of 8′, a quantity much too large to be neglected.* In practice the flexure is got rid of by obtaining the zero of orientation with the telescope pointing nearly in the same direction as during the comparisons for which the zero is required.

If the zero be obtained by swinging the polar axis it will be the *true* zero; but if obtained by allowing the star to traverse the field of its own motion, it will be the *apparent* zero and affected by refraction. It is immaterial which is used in the reductions until the correction for refraction has to be computed; of which more anon.

Reduction of Observations.

Let t_1, t_2 be the sidereal clock times of transit over the middle of the bars, that is the mean of disappearance and reappearance.

T, the mean $= \frac{1}{2}(t_2 + t_1)$.

τ, the half difference $= \frac{1}{2}(t_2 - t_1)$, considered negative if the object be north of the centre.

D, the distance of the middle point of the path described from the centre of the reticule $= 15\,\tau \sin P$.

P, the N.P.D. of the object; or, if used without a suffix, the mean N.P.D. of the two objects.

ΔR.A., ΔN.P.D. the differences of R.A. and N.P.D., and let it be supposed throughout that the southern object is the known, and it is required to find the place of the northern object—the objects being indicated by the suffixes N and S.

Then the approximate

$$\Delta \text{ R.A.} = T_N - T$$

* Bessel, *Astr. Untersuchungen*, i. 14 and ii. 5.

and approximate

$$\Delta \text{ N.P.D.} = D_N - D_S$$
$$= 15\,(\tau_N - \tau\,) \sin P$$

unless too near the pole.

If R be the actual setting of the position-circle (supposed to be graduated in the direction N*f*S*p*), and Z the zero of orientation (either true or apparent), the error of orientation (θ) is obtained with its correct sign from

$$\theta = R - Z.$$

Then the time of describing *mn* (of the figure) is

$$2\tau \sin \theta,$$

and for the N. star the

$$\text{corrected } T_N = T_N + 2\tau_N \sin \theta,$$

and for the S. star the

$$\text{corrected } T_S = T_S + 2\tau_S \sin \theta,$$

and, hence the correction required to ΔR.A. for defective orientation is

$$+ 2(\tau_N - \tau_S) \sin \theta.$$

If $90° + \eta$ be the N. and S. angle of the reticule, the correction required to ΔN.P.D. is

$$- \Delta \text{ N.P.D.} \,.\, \sin \eta,$$

η being constant, a small table may be formed of this correction.

If one of the objects have a proper motion $d\alpha$ and dD in R.A. and N.P.D. in 1^s of time, the correction required to ΔN.P.D. is

$$- 15\tau \,.\, d\alpha \,.\, \sin P,$$

and the correction required to ΔR.A. is

$$+ \frac{\tau \,.\, d\text{D}}{15(1 - \Delta\alpha) \sin P}$$

where τ has the value proper to the object, and is negative if on north side.

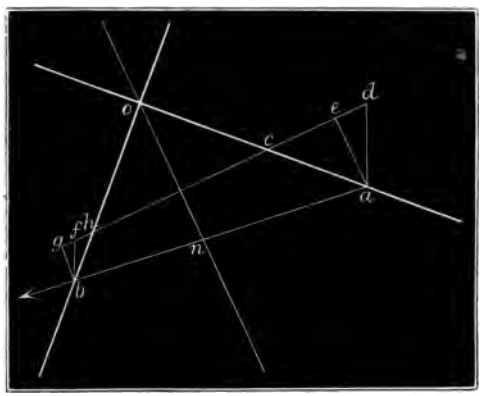
The curvature of path will generally be sensible; the correction required to ΔN.P.D. on this account is

$$-[6\,.\,7367]\,(\tau_N + \tau_S)(\tau_N - \tau_S) \sin P \,.\, \cos P.$$

Correction for Refraction.

Let the stars be east of the meridian; *on* the axis of the reticule exactly oriented; *ao*, *bo* the bars; *ab* the observed path of a star in the inverted field, as affected by refraction; *ad* and

bf, perpendicular to the horizon, the refraction at *a* and *b* respectively. Join *df* and make *ae*, *bg* perpendicular to *dg*, and therefore parallel to *on*.



Then if there were no refraction the star would transit the path *dchg* perpendicular to *on*. *de*, *fg* are the refractions in R.A. which we will call a_1, a_2; *ae*, *bg* are the refractions in N.P.D. which we will call d_1, d_2. In the sense of reducing apparent to true place, the refractions in R.A. are positive when east of the meridian; the refractions in N.P.D. are always positive in the northern hemisphere except in a limited area between the pole and zenith.

Had there been no refraction the star would have been seen at *d* at the instant (t_1) when it was at *a*, and it would have arrived at the point *c* later than t_1 by the time of describing

$$dc\,(=de+ec)=a_1+\frac{d_1}{15\sin \mathrm{P}}.$$

Similarly the star would have been seen at *h* earlier than at *b* by the time of describing

$$hf\,(=hg-fg)=-a_2+\frac{d_2}{15\sin \mathrm{P}}.$$

Therefore

$$\text{corrected } t_1=t_1+a_1+\frac{d_1}{15\sin \mathrm{P}};$$

$$\text{corrected } t_2=t_2+a_2-\frac{d_2}{15\sin \mathrm{P}}.$$

Hence

$$\text{corrected } \mathrm{T}=\tfrac{1}{2}(t_2+t_1)+\tfrac{1}{2}(a_2+a_1)-\tfrac{1}{2}(d_2-d_1)\frac{1}{15\sin \mathrm{P}},$$

and

$$\text{corrected } \tau=\tfrac{1}{2}(t_2-t_1)+\tfrac{1}{2}(a_2-a_1)-\tfrac{1}{2}(d_2+d_1)\frac{1}{15\sin \mathrm{P}}.$$

Putting now τ and d for the refractions at the middle point of the path, δa, δd, the increase of these quantities respectively in two minutes of time (to be explained further on), we have, assuming the refractions to vary symmetrically over the portion of the field utilised,

$$\text{corrected T} = \text{T} + a - \frac{\tau}{120} \cdot \frac{\delta d}{15 \sin \text{P}};$$

$$\text{corrected } \tau = \tau - \frac{d}{15 \sin \text{P}} + \frac{\tau}{120} \delta a,$$

and therefore the correction to ΔR.A. is

$$+ (a_{\text{N}} - a_{\text{S}}) - \frac{\tau_{\text{N}} - \tau_{\text{S}}}{120} \cdot \frac{\delta d}{15 \sin \text{P}},$$

and the correction to ΔN.P.D. is

$$- (d_{\text{N}} - d_{\text{S}}) + \frac{\tau_{\text{N}} - \tau_{\text{S}}}{120} \delta a \cdot 15 \sin \text{P}.$$

With proper attention to the signs of these quantities the above expressions will be correct under all circumstances, within the limits of the assumption that the change of refraction is proportional to the time in all parts of the field, an assumption that can hardly ever introduce sensible error.

At all observatories auxiliary tables are used for facilitating the computation of refraction for extra-meridional observations. The most simple are thus formed:—

Let ZM be the perpendicular from the apparent zenith Z on the hour-circle passing through the star, and PM the arc included between the pole and the foot of the perpendicular; then

$$\sin \text{ZM} = \sin \text{hour-angle} \times \sin \text{colat.}$$

$$\tan \text{PM} = \cos \text{hour-angle} \times \tan \text{colat.}$$

The angle PM, in degrees and minutes, and the log. tan ZM are tabulated with argument every two minutes of hour-angle; the calculations of the refractions in R.A. and N.P.D. are then readily made from

$$\text{Mean refraction in R.A. in seconds of time} = \frac{[0{\cdot}5836] \tan \text{ZM}}{\sin \text{N.P.D.} \cdot \cos (\text{N.P.D.} - \text{PM})}.$$

$$\text{Mean refraction in N.P.D. in seconds of arc} = [1{\cdot}7597] \tan (\text{N.P.D.} - \text{PM}).$$

If desired, these refractions can in a moment be corrected for pressure and temperature of the atmosphere.

The refractions are to be computed for the common hour-angle corresponding to the time, T, and the N.P. distances of either object, which give the four quantities a_{N}, d_{N}, a_{S}, d_{S}. Then adding two minutes to the time, T, the refractions are again computed for one of the objects, and hence are obtained δa and δd.

It is to be noted that the quantities a and d are common to

all differential work, being the refractions depending on N.P.D. The second terms depend upon the variation of the refractions with hour-angle, and are reduced to their simplest form because the bars are inclined 45° to the hour-circle.

If the *apparent* zero of orientation has been employed in the reductions, the second term of the refraction correction in R.A. disappears because the apparent path of the stars is perpendicular to the axis of the reticule.

As an example I will quote an extreme case that occurred at Harrow when observing the Comet *Barnard*, on 1886, April 8.

	h	m	s		°	′	″
Local sid. time	10	27	7	Colat.	38	25	2
☄ approx. R.A.	1	48	34	N.P.D.	56	14	7
✱ „ „	1	47	3	„	56	4	1

Approx. Δ R.A. + 1 30·94, Δ N.P.D. − 10′ 28″·9.

The mean refractions are:—

	h	m	s	″
At	10	27	☄	−20·72 + 469·5
	„		✱	−20·28 + 458·5
	10	29	✱	−20·77 + 474·0

Whence

$$\delta a = -0^{s}\cdot49 \quad \delta d = +15''\cdot5.$$

The mean

$$\tau_{\mathrm{H}} - \tau_{\mathrm{S}} = -50''\cdot6,$$

and, therefore, attending to the signs and remarking that the comet is the *southern* object, we have the corrections for refraction :—

	s	″
First term	−0·44	+11·0
Second term	+0·52	− 2·6
	+ ·08	+ 8·4

If the reticule had been oriented by the apparent motion of the stars the corrections would have been

−0ˢ·44	+8″·4.

Harrow: 1888, *January.*

Note on the Definition of Reflecting Telescopes and on the Images of Bright Stars on Photographic Plates. By Lieut.-General J. F. Tennant, R E., F.R.S.

It has frequently been said that the images of stars are seen in reflecting telescopes without any diffraction rings surrounding them. This statement has always surprised me, because it is accompanied by the statement that the discs are very small compared with those in reflectors. The theoretical investigation which accounts for the rings assumes that the optical rays are rigorously convergent, and this is more true for a well-figured speculum than for an object-glass.

Recently, in looking over a translation of Foucault's *mémoire* on "The Construction of Silvered Glass Specula," I was struck by his statement that he always saw "traces of the rings," and I wrote to M. Henry, who, I believe, follows Foucault's methods almost entirely, inquiring what his experience was. M. Henry kindly informs me that not only does he always see rings with his reflectors, but that they are, in fact, easier to see than with a refractor. In his article on Light I find that Sir J. Herschel states that the rings surrounding star images were discovered by Sir W. Herschel, but he says that they are less easily seen than with a refractor.

I have since calculated the places and brilliancy of the rings to be seen in a telescope with an obstructing disc one-third of the diameter of the aperture, centrally placed, and the result has somewhat surprised me.

Calling e the aperture of the telescope in English inches and s the angular diameter of the ring in seconds, Sir George Airy gives for an open aperture the following values, the unit of brilliancy being the centre of the images:—

es	2·76	3·70	5·16	6·09
Brilliancy	0	$\frac{1}{57}$	0	$\frac{1}{246}$

With one-third stopped centrally as above, which would nearly represent a reflector giving a field of 2° diameter, I find—

es	2·47	3·54	5·44	6·22
Brilliancy	0	$\frac{1}{18}$	0	$\frac{1}{712}$

It would follow that while the central image is smaller and also the first dark ring, the first bright ring would be far more conspicuous than in a refractor, both by its width and brilliancy, compared with the central image.

The place of the third dark ring would be very little inside the corresponding place in a refractor, and so would that of the

third bright ring, which, too, would be less brilliant than in a refractor.

It would require a good deal of labour in interpolating to get the diameters and brilliancy of the rings in a reflector where the small speculum is, as usual, only large enough to show a central object, or about one-ninth of that of the speculum, but it is evident that these would be intermediate between the two sets of values above given, and that there can be no theoretical reason why rings should be absent if carefully looked for under suitable circumstances, provided the figure is good.

I would add that I believe that the great diameter of the images of large stars on photographs will be explained, at all events in part, by the fact that the visible image is by no means all the acting light. If a plate be exposed so as to show stars of the 14th magnitude on the Paris scale, then we shall have sensible impressions made by light whose intensity is $\frac{1}{2 \cdot 5^{13}}$ of that of a 1st magnitude star. Roughly, we may call this $\frac{1}{149000}$ of the light, the distance from the centre of the image at which this fails is far beyond the powers of the integral table given in Sir G. Airy's little book, and I doubt if it could be determined with any accuracy, for at so great a distance the spectra would overlap, and it would be necessary to estimate the total effect of range of those colours which are impressed on the plate. Manifestly, however, the photographic image would be very large, though it does not seem possible it can fill the great space we sometimes see.

Of course light diffused within the photographic film would add its effects to those of incident lights.

P.S.—In a more recent communication M. Henry tells me that they some time ago tried specula up to 50 cm. (nearly 20 inches) with various sized patches, and under favourable circumstances found just such a brilliant ring as I have described.

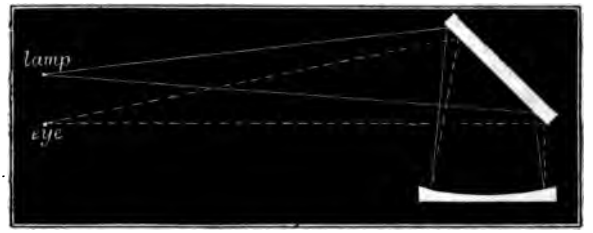
Note on Testing Polished Flat Surfaces.

By A. A. Common, F.R.S.

The following method of testing flat surfaces has some advantages over the methods generally employed, and is particularly useful in enabling the errors to be localised exactly. It is an extension of Foucault's method of testing concave surfaces, and consists in putting on the flat surface to be tested, in the cone of rays coming from a concave surface in the process of testing by Foucault's method, and thus finding the effect of the reflection on the course of the rays.

The concave mirror should strictly be quite spherical and, of course, somewhat larger than the plane surface to be tested, but an ordinary speculum will do almost as well; any errors that

the concave may have can be separated from the errors of the flat by rotating the one or the other and so taken account of.



The diagram given shows at once the arrangement, from which it will be seen that in this case the plane mirror receives the light from the lamps and from the mirror also, so that any error of the plane mirror would be doubled before reaching the eye.

In order to use this plan the method of testing concave surfaces described by Foucault must be thoroughly understood, as the one is only an extension of the other, and the pinhole, the straight line or system of squares, and the screen are to be used exactly as testing a concave mirror, but the whole of the testing can be done at the centre of curvature, and if a strictly spherical mirror be used the test can be made almost a rigid one.

Notes on the Solar Surface of 1887. By S. J. Perry, D.Sc., F.R.S.

Having just completed the measurement of the Sun's spot-area observed at Stonyhurst in 1887, I thought that some of the results might fitly be brought at once before the Society. The number of days in each month in which drawings were obtained was respectively 11, 18, 24, 22, 22, 28, 30, 25, 21, 23, 17, and 18, making a total of 259 days in the course of the twelve months.

When the areas had been reduced to millionths of the solar hemisphere and represented graphically, the first point that struck the eye was the prolongation of the minimum period during the first four months of the year, with its sudden cessation at the opening of May. We have thus already in this eleven-year period two minima, one lasting from September 22 to December 8 of 1886, or for two months and a half, and the other extending over the first third of 1887, more than twice as many days without spots being noted in the second period than in the first. But if we include both these periods in the same minimum, by neglecting the interruption at the close of 1886, then the whole minimum period includes 222 days, and the date of the minimum may be given approximately as January 10, 1887. In thus speaking of the minimum I do not wish it to be inferred

that the absolute minimum of the eleven-year period was reached on January 10, 1887. It would, of course, be premature to venture upon such an assertion, as we may not unreasonably look forward to even longer periods of solar inactivity during the years 1888 and 1889 than that which marked the end of 1886 and the beginning of 1887.

From May to August of the year that has just expired there was a considerable wave of disturbance corresponding to each rotation of the Sun, and these differed little in extent, although they were by no means periodic returns of the same groups to the visible hemisphere. For most of the larger spots and groups of spots have this year lasted but for a short time; one group only—namely, that which was first observed on January 27—having lasted for part of three revolutions. This group was finally observed as three small dots on March 22, but the faculæ of the group were still a conspicuous object during the next rotation. On seven days only was the Sun observed to be free from spots between May 1 and August 24, but from this date until November 30 the solar surface was more quiet, and thirty-five days are recorded as spotless. During the last month the spotted area has been larger than in any month since May 1886, December 15 being the date of the recent secondary maximum. The group visible from July 22 to the 30th was a typical case of the formation of a spot, the slight dot surrounded by a few faculæ being the first indication of the coming disturbance.

I should like for a moment to call attention to the secondary maximum that occurred in 1886, as there exists a marked difference between the results published by Wolf and by Tacchini; most of the results given by the former pointing to the beginning of March, and the latter giving April 1 as the date of the maximum. The Stonyhurst curve shows three maxima in 1886 in the following order as regards magnitude: March 8, May 2, and April 2, the spot area in millionths of the hemisphere being respectively 2,459, 2,274, and 1,575. As observations were very frequent at all these dates, and the results of consecutive days hold well together, I can scarcely believe that the state of the sky will suffice to account for such great discrepancies as would have to be admitted in order to accept the date of Prof. Tacchini.

Another point of some interest is the behaviour of the veiled spots during the period of minimum. These spots have for convenience of record been divided into three classes. The first class comprises those misty patches, large in extent, but of very short duration, which give an appearance of bad definition to whole regions of the solar surface. These, which were frequent about the time of maximum, have scarcely been seen at all this year. The second class, consisting of penumbral dots, which increase in size and then coalesce with other similar spots in their immediate neighbourhood, the total duration of any single spot never much exceeding three minutes, have been as frequent and as easily seen this year as they ever were before, but the

changes they have undergone during their short existence have not been so extended lately as in previous years. The third class of veiled spots, which differ from the two other classes in being confined to the spot zones, in their duration extending sometimes to several days, and in their close resemblance to minute patches of penumbra, have been observed this year rather less often than in 1883 and 1884. These faint objects have been examined both on the projected image and directly by aid of a solar prism and a Dawes eyepiece, and it is invariably found not only that the observation is far more easy, but more perfect in every way when the Sun is viewed by projection.

On October 28, at $9^h\ 5^m$, a few faculæ attached to a group of faint spots became on a sudden intensely bright, and faded again as quickly as they had shone out.* During this appearance no other change of any importance occurred in the spots themselves or in their neighbourhood. Within three minutes both the faculæ and the spots had entirely disappeared. I may mention in conclusion that, although there have been this year many days without true spots, the Sun's surface has but rarely been entirely free from faculæ, which, however, were sometimes very faint.

Nebula in Andromeda and Nova, 1885. By T. W. Backhouse.

I. Magnitude of Nova.

The few observations I took of *Nova*, 1885, quite confirm the remark of Dr. Copeland in his paper in *Monthly Notices*, xlvii. p. 55, that lower powers showed it brighter than higher ones. The comparison stars and their magnitudes, as given in the *Durchmusterung*, as well as the adopted magnitudes based on these from estimates, are shown in the following table:—

No. in D.M.	Mag. in D.M.	Magnitude adopted.
40°, 158	7·5	7·25
39, 167	7·1	7·46
39, 166	8·5	8·69
41, 149	9·1	8·91
40, 145	9·0	9·02

The resulting magnitude of *Nova* with the different powers, 9 being the finder of telescope, and the other figures the approximate powers used on a $4\frac{1}{4}$-inch refractor, is as follows:—

* The Stonyhurst Magnetograms do not show any trace of this solar disturbance.

Power used.	1885 Sept. 3 $10\frac{1}{2}^h$.	Sept. 5 $10.^h$.	Sept. 9 11^h.	Sept. 16 11^h.	Sept. 24 11^h.	Oct. 1. 11^h.
9		7·5				
2-in. refractor	7 5					
38			7·9	8·4	9·0	
76		8·3			9·2	9·0
143			8·7			9·4

The star had so far declined in brightness as to be described as *very faint* with powers 76 and 143 on October 27; *quite faint* with power 76 on November 4.

II. Brightness of Nebula.

Estimates of the total light of the nebula itself were made, the comparison stars used being σ, ν, θ and ρ *Andromedæ*, whose magnitudes are modified from those of the *Harvard Photometry* according to their average positions in the sequences observed, thus:—

	H.P.	Adopted.
σ Andromedæ	4·65	4·50
ν ,,	4·42	4·57
θ ,,	4·30	4·82
ρ ,,	5·27	5·27

	Mag. of Nebula.
1885, Sept. 3	4·81
9	4·84
Oct. 1	4·91
1887, Oct. 21	4·70
Nov. 14	5·01
15	4·73
Dec. 4	4·81

The discordances of the results are no larger than might be expected, the comparison of a large area of light, like the nebula, with the stars not being very easy. These observations, therefore, do not show any appreciable increase of the brightness of the nebula arising from the presence of the new star, compared with its present light; the stellar nucleus from its faintness was, indeed, not likely to add perceptibly to the total light.

III. The Spectrum.

I made the following notes on the spectrum of the new star:—

1885, *September* 16.—Its spectrum is partly continuous, but there is certainly interrupted light as well, which must be either

bright lines or short bright spaces between broad absorption bands; I believe the former. There are certainly two bright spots (lines appear as spots with the apparatus used), one probably in the green, much plainer than the other, which is half-way from it to the red end. I strongly suspect a third at an equal distance on the other side of the brightest. The general appearance of the whole spectrum of star and nebula is very much like that of an ordinary comet.

November 5.—There can be no doubt the spectrum of the new star is highly interrupted, and I have little doubt it contains more than one definite bright line. The brightest is about at the brightest part of the spectrum of the nebula, which is continuous as far as I can see, though there may be brighter bands in its centre, but this suspected appearance may only be caused by the star's spectrum.

1886, *February* 1.—I think the spectrum of the nucleus of the nebula is not simply continuous, but has two or three or more bright bands on it; this may, however, be only imagination.

1887, *December* 7.—The spectrum of the nebula is certainly mainly continuous, though I suspect a bright line in the brightest part as well as other very slight irregularities, but I cannot be sure of any of them.

December 10.—With a low power the spectrum mostly appears quite continuous, though I sometimes have a faint suspicion of a very feeble line or lines.

All the above observations were made with a Browning miniature spectroscope on a 4¼-inch refractor by Cooke; the following was made without any telescope, merely using one or two prisms of dense flint glass, both with and without spectacles in addition:—

1887, *December* 9.—The spectrum seems perfectly continuous, without the slightest sign of any lines, a great contrast to that of the Great Nebula in *Orion* which, viewed in this manner, consists of two conspicuous bright lines.

Sunderland: 1887, *December* 22.

The Chief Meteor Showers. By W. F. Denning.

I have derived from my observations during the last fifteen years the following mean places for the radiants of the leading showers. The positions are corrected for precession, and brought up to 1890:—

Name of Shower.	Duration.	Date of Max.	Radiant Point. α δ	Sun's Longitude.
Quadrantids	Dec. 28–Jan. 4.	Jan. 2	229°·8 + 52°·5	281°·6
Lyrids	April 16–22	April 20	269·7 + 32·5	31·3
η Aquarids	April 30–May 6	May 6	337·6 − 2·1	46·3
δ Aquarids	July 23–Aug. 25	July 28	339·4 − 11·6	125 6
Perseids	July 11–Aug. 22	Aug. 10	45·9 + 56·9	138·5
Orionids	Oct. 9–29	Oct. 18	92·1 + 15·5	205·9
Leonids	Nov. 9–17	Nov. 13	150·0 + 22·9	231·5
Andromedes	Nov. 25–30	Nov. 27	25·3 + 43·8	245·8
Geminids	Dec. 1–14	Dec. 10	108·1 + 32·6	259·5

Notes.

Quadrantids.—Heis was the first to determine this radiant accurately. It was subsequently observed by Masters and Prof. Herschel (1863–4). The radiant is circumpolar in this latitude, but low down during the greater part of the night, hence the display is usually seen to the best advantage on the morning of Jan. 2.

Lyrids.—Attention was first drawn to the April meteors by Herrick in the United States (*B. A. Report*, 1871, p. 42). The probable identity of this meteor orbit with Comet I., 1861, was pointed out by Galle and Weiss. The earlier observers of this stream placed the radiant too far N.E., and the assumed accordance was therefore considered doubtful. My recent observations prove that the radiant is identical with that computed for the comet of 1861, and it exhibits a displacement to the E., as observed on successive nights. Prof. Herschel gives the cometary radiant as 270°·5 + 32°, April 20, Corrigan, 270°·9 + 33°·5.

η Aquarids.—Further observations are urgently required of this stream. The radiant is only visible for a short time before sunrise. There is a considerable difference between my results and those secured by Col. Tupman, the discoverer of this system in 1870, whose observations place the radiant at 326½ − 2½ April 29–May 3. These May Aquarids are interesting from the fact that they present an orbital resemblance to Halley's Comet which makes a near approach to the earth on May 4, twelve days before reaching the descending node. (See *Monthly Notices*, xlvi. p. 396–8.)

δ Aquarids.—The meteoric epoch, July 26–30, was first pointed out by Quetelet many years ago. Biot also found, from the oldest Chinese observations, a general maximum between July 18 and 27 (Humboldt). Showers of Aquarids were remarked by Schmidt, Tupman (1870), and others, but it was not known until observations in 1878 by the writer that the Aquarids formed the special display of the epoch, and that there were many early Perseids visible at the same time.

Perseids.—Muschenbroeck, in his work on "Natural Philosophy," printed in 1762, mentions that he observed shooting stars to be more numerous in August than in the other months of the year. Quetelet, in 1835, was, however, the first to attribute a definite maximim to the 9th–10th. This stream is remarkable for its extended duration, and for the obvious displacement which occurs from night to night in the place of its radiant (see *Monthly Notices*, xlv. pp. 97–8). The period of visibility appears to cover the forty-three nights from July 11 to August 22 inclusive, and the radiant advances from 11° + 48° to 76° + 57°. This shower apparently varies but little in its annual richness. In the morning of August 11 it usually yields from sixty to eighty meteors per hour for one observer. The centre of radiation on August 10 agrees with the

radiant assigned to Comet III., 1862, viz. 43°+57°·5 (Herschel), and 43°·8+57°·2 (Corrigan).

Orionids.—Profs. Schmidt and Herschel were the first to discover the Orionids as the most brilliant display of the October period, and accurately determined its radiant in 1863-4-5. Herrick recorded a shower at 99°+26°, Oct. 20–26, 1839, and Zezioli in 1868 recorded many meteors which were ascribed to a radiant at 111°+29°, but there is no doubt that the Orionids were observed in both these cases, though the radiant was badly assigned. There is a contemporary shower at 106°+22°, close to δ *Geminorum*, which is liable to be confused with the Orionids, but the latter is by far the richest of the pair. The radiant of the Orionids shows no displacement like the Perseids.

Leonids.—Observed from the earliest times. Humboldt and Bonpland saw it well on the night of November 11-12, 1799, and the phenomenon at its magnificent return on November 12, 1833, was ably discussed by Olmsted. It furnished a splendid shower in 1866, November 13, and many meteors were seen at the few subsequent returns. During the last fifteen years the displays have been extremely meagre. There is no doubt, however, that the meteors form a complete ellipse, for the earth encounters a few of the particles at every passage through the node. But the meteors are nearly all massed in the neighbourhood of their parent, Comet I. 1866, which gives a radiant at 150°·5+23°·5, November 13 (Herschel), and 150°·4+22°·8 (Corrigan). It is supposed that there are minor groups of meteors pursuing the same orbit; if so we may have a revival of this display in 1888, for "on the night of November 12, 1822, shooting stars mingled with balls of fire were seen in vast numbers at Potsdam by Klöden" (Lardner's *Museum*).

Andromedes.—Observed by Brandes, at Hamburg, December 7, 1798. It also recurred in 1838; the very brilliant showers of November 27, 1872 and 1885, are still fresh in the memory. It is uncertain whether this group forms an unbroken stream; if so, the regions far removed from the comet must be extremely attenuated. Some of the meteors were seen in 1877 and 1879. The radiant is diffuse to the extent of 7° or 10°. The cometary radiant is at 23°·4+43°·4 (Weiss), and 24°+43°·2 * (Corrigan), which is very close to the meteoric centre. Returns of the shower should be looked for in 1892 and 1898.

Geminids.—Mr. Greg first called attention to the importance of this shower. It was well observed by Prof. Herschel in 1861–3–4, and some later years.

Bristol: 1887, *December.*

Heights of Fireballs and Shooting Stars. By W. F. Denning.

While occasionally engaged during the past year in computing meteor heights, I was led to compare the relative elevations of fireballs and ordinary shooting stars. The former before extinction appear to penetrate much lower in the air than the latter. From the real paths of the fireballs and smaller meteors seen by myself and other members of the Liverpool Astronomical Society at the end of 1886 and during 1887, it appears that the height of fireballs at disappearance is only about one-half that of shooting stars, the figures being 25 and 54 miles respectively. But these values are based on only 20 observations, and are, therefore, far from being conclusive. They are, however, amply

* These positions by Mr. Corrigan are taken from the *Sidereal Messenger*, May 1886.

confirmed by numerous records contained in the *Luminous Meteor Reports of the British Association*, the *Monthly Notices*, Heis's *Resultate der in den* 43 *Jahren* 1833–1875 *angestellten Sternschnuppen-Beobachtungen*, and other publications.

The mean heights, in British statute miles, of the best observed and most brilliant fireballs of the last twenty years or so, as computed by Prof. Herschel, Col. Tupman, and many others, and described in consecutive volumes of the *B. A. Reports*, *Monthly Notices*, &c., are as follow :—

	Height at beginning.	Height at ending.
80 fireballs, 1865–1887	69·2 miles	30·2 miles

Let us compare with these figures the mean heights of meteors (nearly all shooting stars of the 1st mag., or fainter) which I have derived from a collection of the results given by several different authorities :—

	No. of Meteors.	Height at beginning.	Height at ending.
E. Heis, *Resultate, &c.*	271	76·9 miles	50·1 miles
A. S. Herschel, *B. A Reports*	86	79·5 ,,	53·3 ,,
T. H. Waller, *B. A. Report*, 1874	48	81·4 ,,	52·4 ,,
W. F. Denning, shooting stars seen in 1887	13	80·0 ,,	54·2 ,,

The average height of nearly all the meteors seen up to the end of 1862 (*B. A. Report*, 1863, p. 328) was—

At beginning.	At ending.
70·05 miles	54·22 miles.

These, however, included a proportion of fireballs. The mean heights deduced from the calculations of Heis, Herschel, and Waller, given in the above summary, are 79·3 and 51·9 miles, but a few fireballs were interspersed amongst these observations (though the great bulk of them consists of ordinary shooting stars), hence the values are perhaps slightly below the elevations that would be derived from the smaller meteors alone. A careful discussion of the various records gives the following mean relative heights :—

	At beginning.	At ending.	At mid-course.
Fireballs	69 miles	30 miles	49½ miles
Shooting stars	80 ,,	54 ,,	67 ,,

It appears from this that before attaining a visible degree of incandescence fireballs are usually eleven miles lower in the atmosphere than small meteors, and that upon final disruption they are twenty-four miles nearer the earth than the fainter class. The heights at mid-course differ by nearly eighteen

miles. It is also extremely probable that telescopic meteors are at yet greater elevations than the brighter forms of these bodies visible to the naked eye.

Bristol: 1887, *December.*

On Invisible Stars of Perceptible Actinic Power.

By Dr. R. de Kövesligethy.

(*Communicated by the Astronomer-Royal.*)

With reference to his well-known photographs of the small star in the annular nebula in *Lyra*, M. von Gothard was so kind as to call my attention to the possibility of a theoretical treatment of the question as to the existence of invisible stars of perceptible actinic power. The question may be generally resolved without the aid of any explicit law of emission. As I think the results may be of some importance as bearing upon the proposed photographic work shortly to be undertaken, I may be allowed to briefly point them out.

I exclude all stars of *merely* homogeneous ultra-violet light, not only because these cases may be very rare, but chiefly because the invisibility of such a star would be of no further account. I select rather stars of well-developed continuous spectra. Then, to speak briefly, I consider two methods of photometric observations as *different* when they select out of the spectrum a group of rays between *different* limits of wave-length. Thus eye observations and photographs of stars are regarded as different, the former limiting the star's spectrum between the Fraunhofer lines H and A, and the latter between about P and *h*. The influence of different sensibility of the two methods may be omitted, for it does not alter at all the following theoretical theses:—

(1) For two proposed methods of observation there exists at least one substance giving a continuous spectrum such that the total intensity of the light between defined limits is the same by both methods, or conversely.

(2) For any substance giving a continuous spectrum there are at least two methods of observation for which the intensity of the light within defined limits has the same value.

The theorem is evidently demonstrated if I could prove that the emission function contains at least two parameters not simultaneously eliminable.

Let I be the intensity of the ray of wave-length λ, θ the absolute temperature, $z_1, z_2 \ldots z_n$ certain quantities depending

partially or totally upon the temperature and substantial qualities. Then generally we have

$$I=f(\lambda, \theta, z_1, z_2 \ldots z^n).$$

That the number of parameters is at least two, which are not simultaneously eliminable, i.e. are not replaceable in the above equation by a single parameter, θ by virtue of a relation

$$\theta=\phi(\theta, z_1, z_2 \ldots z_n)$$

may be proved as follows.

According to the law of Clausius (Ueber die Concentration von Wärme u. Lichtstralen, "Pogg. Ann." cxxi. pag. i) the emission of absolutely opaque bodies in different media is proportional to the square of the refractive index, and as absorption proves independent of the surrounding medium we may say the same for any emission at all. If there were now but one parameter in the emission function, or if, when more, they were simultaneously eliminable, we should have the equation

$$n^2 f(\lambda, \theta)=f\left(\frac{\lambda}{n}, \theta\right),$$

which we could differentiate to θ, to obtain the law for a body physically similar, and eliminate θ from the two equations. The result would be

$$F(\lambda, n)=0,$$

i.e. the equation of relative dispersion of the two media *independent* of substantial qualities. As this equation is absurd the supposition must be false; there are at least two independent parameters in the emission function.

Now let λ_1 and λ_2, λ^1 and λ^2 be the limiting wave-lengths between which two different methods of photometric observation give a continuous spectrum with the intensities L_1 and L^1, which may be quite independent of each other; then we have the following pair of simultaneous equations:

$$\int_{\lambda_1}^{\lambda_2} f(\lambda, \theta, z_1, z_2 \ldots z_n)d\lambda = L_1$$

$$\int_{\lambda^1}^{\lambda^2} f(\lambda, \theta, z_1, z_2 \ldots z_n)d\lambda = L^1$$

a solution of which, according to the demonstrated theorem, can always be found, since the members on the left contain at least two arbitrary parameters. The only conditions to which L_1 and L^1 are subject, are

$$\int_0^\infty f(\lambda, \theta, z_1, z_2 \ldots z_n)d\lambda > L_1, L^1 > 0.$$

When L_1 is smaller than the smallest perceivable intensity for

eye observation, L^1 greater than the least sensibility of photographic plates, we have M. von Gothard's case with the *Lyra* star; and since the possibility of the existence of such stars may be also proved theoretically, M. von Gothard's opinion that there might be found still more of these interesting objects may easily be verified during the general photographic survey of the heavens.

Budapest: January 12, 1888.
Meteorologische Centralanstalt.

Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1887. No. XI.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. xxxvi. p. 318, vol. xxxvii. p. 32, vol. xxxviii. p. 493, vol. xli. p. 109, vol. xlii. p. 230, vol. xliii. p. 81, vol. xliv. p. 89, vol. xlv. p. 330, vol. xlvi. p. 126, and vol. xlvii. p. 101. The observations were made with the "half-prism" spectroscope, one "half-prism" with a dispersion of about $18\frac{1}{2}°$ from A to H being used throughout. A magnifying power of 14 was employed.

The cylindrical lens has always been used in front of the slit as in the observations made previously to 1881 and since. The observations of the Moon and of the sky have been made as a check on the general accuracy of the results.

The day specified in the first column is the civil day, and the hour is that of Greenwich civil time, commencing at Greenwich mean midnight, and reckoning from 0 to 24 hours.

The observations were made by Mr. Maunder throughout.

Motions of Stars in the Line of Sight in Miles per Second, observed with the Half-prism Spectroscope.

(+ denotes Recession; − Approach.)

Date. 1887.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Concluded Motion of Star. Estimd.	Remarks.
				α Andromedæ.			
Sept. 1	0	2	F	− 9·2	−23·0	−26·0	Spectrum fairly steady.
Oct. 14	23	2	F	+ 2·5	− 5·9	− 7·1	Spectrum steady but rather faint.
19	21	2	F	+ 3·9	−26·1	−26·8	Definition fair.
21	22	4	F	+ 4·5	−24·2	−25·1	Spectrum fairly steady.
				β Cassiopeiæ.			
Oct. 19	22	2	F	− 1·5	+ 7·9	+ 7·6	Measures very rough.

Date. 1887.	h	No. of Meas	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				γ Pegasi.			
Sept. 1	0	4	F	− 8·7	−22·7	−23·2	Definition fair.
Oct. 14	23	2	F	+ 4·3	−25·9	−27·2	Measures made with great difficulty.
19	21	2	F	+ 5·7	−20·6	−21·0	Spectrum faint but steady.
				α Cassiopeiæ.			
Oct. 19	23	2	F	− 2·2	+13·9	+11·3	Observations made with great difficulty.
Nov. 1	0	2	b_1	+ 0·5	+58·8	+55·7	Definition fair.
				β Ceti.			
Oct. 28	23	2	b_1	+ 9·8	−67·0	−66·4	Spectrum faint and tremulous.
				γ Cassiopeiæ.			
Feb. 16	20	6	F	+12·0	+ 1·7	− 1·9	Star-line seen with difficulty. Measures rough.
Oct. 19	23	2	F	− 3·4	−17·1	−21·0	Star-line faint and broader and more diffused than usual.
				β Andromedæ.			
Oct. 28	23	2	b_1	+ 1·9	+31·7	+26·4	Spectrum bright but tremulous.
Nov. 1	0	2	b_1	+ 2·8	+26·7	+27·9	Definition fair.
				β Arietis.			
Oct. 21	22	2	F	−1·4	+48·8	+51·7	Definition fair.
				γ Andromedæ.			
Feb. 16	20	2	F	+16·1	−13·4	−12·8	Star-line faint.
Nov. 1	0	2	b_1	− 1·2	−19·8	−19·2	Star-line faint.
				α Arietis.			
Oct. 15	0	2	F	− 4·7	− 0·5	− 4·4	Spectrum and star-line faint.
21	22	4	F	− 2·6	+20·0	+25·5	Measures very rough.
28	23	4	b_1	− 0·3	+ 2·2	+ 5·0	Spectrum bright but tremulous.
				α Ceti.			
Oct. 28	23	4	b_1	− 2·4	+ 0·9	+ 2·4	It seems clear that the edge of the dark fluted band in this star is not the b_4 line. Assuming the observations of the b_1 line to be correct, the wave-length of the edge of the band, corrected for motion of earth and star, will be $\lambda = 5162{\cdot}63$, Ångström's value, 5166·88, for b_4 being assumed.
29	0	2	b_4	− 2·4	−137·1	−168·0	

Date. 1887.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				β Persei.			
Jan. 26	22	4	F	+16·6	−90 0	−93·7	Definition bad.
28	20	4	F	+16·8	−16·5	−13·0	Definition poor.
31	20	5	F	+17·0	−18·4	−17·0	Definition bad.
Feb. 2	23	4	F	+17·1	−108·6	−105·2	Definition poor.
15	23	6	F	+17·4	−51·0	−49·0	Definition poor.
16	20	6	F	+17·4	−44·0	−40·9	Definition poor.
Oct. 20	0	4	F	− 8·1	−51·4	−52·8	Definition fair.
21	22	4	F	− 7·6	−81·3	−63·2	Definition good.
24	23	4	F	− 6·8	−38·7	−25·7	Definition fair.
				α Persei.			
Feb. 16	20	4	F	+16·3	−12·4	−11·3	Star-line of Procyon type.
Oct. 20	0	2	F	− 9·0	−26·9	−27·6	Definition fair.
21	23	2	F	− 8·6	−55 5	−53·1	Definition variable.
24	23	2	F	− 7·9	−42·4	−39·9	Definition fair.
				Aldebaran.			
Jan. 28	21	2	F	+16·4	+20·8	+29·3	Definition poor.
Feb. 16	21	2	F	+18·4	+24·9	+29·1	Definition fair.
Oct. 15	1	2	F	−13·5	+47·5	+47·1	Star-line seen with difficulty.
20	1	3	F	−12·4	+47·7	+49·3	Definition poor.
22	1	4	F	−11·9	+43·4	+49 6	Definition poor.
25	0	2	F	−11·1	+60·8	+54·6	Definition poor.
29	0	4	b_1	−10·1	+42·2	+45·7	Definition poor.
				Capella.			
Jan. 26	22	4	F	+12·6	+ 3·8	+ 8·1	Definition fair.
Feb. 16	0	2	F	+15 9	+18·5	+20·3	Definition poor.
Oct. 22	0	4	F	−13·5	+52·3	+52·7	Definition good.
25	0	4	F	−13·0	+38·4	+41·9	Star-line seen well occasionally.
29	1	4	b_1	−12·1	+52·7	+60·3	Star-line seen with difficulty.
				Rigel.			
Jan. 27	0	2	F	+12·7	+14·5	+18·9	Star-line very faint.
31	21	2	F	+13·5	+23·9	+10·8	Definition fair.
Feb. 3	0	2	F	+13·8	+13·5	+12·7	Measures rough.
12	22	2	F	+15·0	+ 1·0	+ 1·7	Definition poor.
16	21	2	F	+15·4	− 5·0	− 0·9	Definition poor.

Date. 1887.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
Oct. 20	1	2	F	−12·0	+32·4	+36·4	Definition poor.
22	0	6	F	−11·6	+28·7	+28·8	Spectrum bright but tremulous.
25	0	2	F	−11·1	+45·7	+37·2	Definition good.
				γ Orionis.			
Jan. 31	22	2	F	+14·4	−23·7	−21·7	Definition fair.
Feb. 12	22	2	F	+16·3	+26·2	+26·0	Definition fair.
16	22	4	F	+16·8	−12·6	−12·9	Definition fair.
Oct. 22	0	2	F	−13·8	+ 8·7	+ 9·3	Definition good.
25	1	4	F	−13·3	+16·5	+17·6	Spectrum bright but tremulous.
				β Tauri.			
Jan. 31	22	2	F	+14·6	−24·5	−21·9	Cloud passing.
Feb. 16	22	2	F	+17·2	−10·0	−10·5	Definition good.
Oct. 22	0	4	F	−14·7	−19·6	−12·3	Definition fair.
25	1	4	F	−14·1	− 0·6	− 5·5	Definition fair.
				δ Orionis.			
Feb. 16	21	4	F	+15·8	+11·4	+12·8	Definition poor.
Oct. 25	1	4	F	−13·0	+ 4·7	+10·9	Definition fair.
				ε Orionis.			
Feb. 16	21	2	F	+15·6	+16·8	+18·0	Definition fair.
Oct. 25	1	2	F	−13·1	+34·5	+34·8	Definition fair.
				ζ Orionis.			
Feb. 16	22	4	F	+15·4	−23·6	−20·1	Definition fair.
Oct. 25	1	4	F	−13·2	+11·7	+14·3	Definition fair.
				κ Orionis.			
Feb. 16	22	2	F	+14·1	−28·4	−25·3	Star-line faint.
				α Orionis.			
Oct. 29	1	2	b_1	−14·1	+69·3	+77·0	Spectrum bright but tremulous.
29	1	2	b_4	−14·1	+77·2	+76·0	Star-lines held with difficulty.
				β Aurigæ.			
Oct. 22	0	2	F	−15·0	+41·3	+41·7	Definition fair.
25	0	2	F	−14·5	+32·4	+33·4	Definition good.

Date. 1887.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				γ Geminorum.			
Feb. 16	22	2	F	+14·4	−74·7	−64·8	Spectrum bright and steady.
				Sirius.			
Jan. 27	0	2	F	+ 6·0	−25·8	−27·0	Definition bad.
Feb. 3	0	6	F	+ 7·6	+12·7	+12·4	Definition fair.
12	21	4	F	+ 9·6	−13·0	−11·3	Spectrum very tremulous.
16	23	6	F	+10·3	− 6·8	− 7·5	Measures very rough.
Oct. 25	2	6	F	−13·6	+36·2	+34·4	Spectrum very tremulous.
				Castor.			
eb. 3	1	2	F	+ 8·0	−35·9	−36·2	Definition fair.
16	0	4	F	+11·5	−17·7	−15·1	Definition poor.
				Procyon.			
Feb. 3	1	2	F	+ 6·2	+20·2	+20·2	Definition good.
16	23	4	F	+10·0	−10·7	− 7·5	Spectrum very tremulous and star-line faint.
Oct. 29	3	4	b_1	−17·6	+54·0	+58·5	Star-line very faint indeed.
				Pollux.			
Feb. 16	1	2	F	+10·8	−44·4	−38·7	Definition poor.
Oct. 29	2	4	b_1	−18·0	−53·5	−51·2	Definition poor.
				Arcturus.			
July 4	23	2	F	+15·0	−43·3	−45·1	Definition poor.
11	23	2	F	+15·2	−43·3	−44·5	Definition poor.
				α Coronæ Borealis.			
July 11	23	2	F	+11·8	+20·7	+20·7	Spectrum tremulous.
Aug. 24	22	2	F	+12·1	−32·9	−30·8	Star-line seen with great difficulty; spectrum faint; measures rough.
				α Ophiuchi.			
July 12	0	2	F	+ 6·9	−21·5	−21·0	Definition poor.
Aug. 24	22	2	F	+13·7	−43·6	−34·4	Spectrum faint; definition bad.

Date. 1887.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				Vega.			
July 12	0	2	F	+ 0·8	−38·1	−41·5	Definition fair.
Aug. 22	23	2	F	+ 6·1	−54·0	−55·5	Definition good.
24	23	2	F	+ 6·3	−63·1	−47·8	Definition bad.
31	23	4	F	+ 6·9	−51·3	−58·3	Definition poor.
Sept. 2	21	2	F	+ 7·1	−47·2	−49·3	Definition good.
Oct. 10	21	2	F	+ 8·7	−55·6	−57·5	Definition fair.
14	20	2	F	+ 8·7	−43·4	−41·4	Spectrum faint; slit narrow.
				γ Lyræ.			
Aug. 22	23	2	F	+ 6·5	−57·3	−51·8	Spectrum faint; measures rough.
				ζ Aquilæ.			
Aug. 23	0	2	F	+ 9·6	−27·1	−27·4	Spectrum faint; measures rough.
				δ Cygni.			
Oct. 10	22	4	F	+ 7·1	−25·1	−25·9	Spectrum faint; measures rough.
				Altair.			
July 12	1	2	F	− 2·9	−39·8	−40·4	Definition fair.
Aug. 23	0	2	F	+ 7·7	−53·3	−57·1	Star-line faint.
25	0	2	F	+ 8·1	−50·3	−39·2	Definition poor.
31	23	4	F	+ 9·7	−71·0	−63·5	Star-line very ill-defined.
Oct. 10	21	2	F	+15·7	−13·6	−15·7	Definition good.
14	21	2	F	+15·9	−16·9	−22·8	Definition fair.
				γ Cygni.			
Oct. 14	21	2	F	+ 8·5	−29·6	−35·2	Spectrum faint; definition fair.
31	21	4	b_1	+ 9·8	−20·3	−18·3	Definition bad; measures rough.
				α Cygni.			
Aug. 23	0	2	F	− 0·7	−43·1	−44 6	Definition good.
31	23	2	F	+ 0·7	−47·5	−47·1	Definition fair.
Oct. 14	21	2	F	+ 6·8	−39·0	−33·5	Spectrum faint but steady.
31	21	2	b_1	+ 8·4	−93·3	−80·8	Definition bad; measures rough.

Date. 1887.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				ε Cygni.			
Oct. 14	21	2	F	+ 9·9	− 1·4	+ 1·5	Spectrum faint; measures rough.
31	22	4	b_1	+11·5	−11·8	−11·5	Definition bad; measures rough.
				α Cephei.			
Aug. 23	1	2	F	− 4·3	−47·5	−47·1	Definition fair.
Oct. 14	22	2	F	+ 1·2	−60·6	−58·3	Spectrum faint.
				ε Pegasi.			
Oct. 14	22	2	F	+13·3	+26·5	+32·4	Star-line faint, but sharp.
31	23	2	b_1	+16·0	+ 5·1	+ 4·4	Definition bad; measures rough.
				β Pegasi.			
Oct. 28	22	2	b_1	+ 9·6	−56 9	−51·5	Spectrum rather faint, but definition good.
28	22	4	b_4	+ 9·6	−56·6	−54·1	
31	23	2	b_1	+10·3	−20·7	−20·5	Spectrum faint and tremulous.
				α Pegasi.			
Sept. 1	0	4	F	− 4·0	−25·9	−29·8	Spectrum faint; measures rough.
Oct. 14	23	2	F	+ 8·5	− 5·6	− 4·0	Spectrum faint; sky clouding.
19	20	2	F	+ 9·8	−22·7	−23·5	Definition fair.
24	22	2	F	+11·1	−31·3	−32·8	Definition good.
				Great Nebula in Orion.			
Oct. 25	2	6	F	− 5·0	−12·4	− 7·4	Spectrum faint; measures rough.

Moon.

Date.	h	No. of Meas.	Line.	Motion Measured.	Remarks.
Jan. 31	19	5	F	+ 1·5	The coincidence of the two spectra appeared perfect.
Feb. 3	0	5	F	+ 1·6	
July 12	1	5	F	+ 0·0	
Sept. 1	0	5	F	+ 0·8	
Oct. 24	22	5	F	− 1·3	
28	23	5	b_1	− 1·3	
Nov. 1	1	5	b_1	− 1·0	

Sky.

Oct. 11	12	5	F	+ 5·3	Slit rather wide.
22	12	5	F	+ 1·9	The coincidence of the two spectra appeared perfect.

Observations of Occultations of Stars by the Moon, and Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1887.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day of Obs.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1887, Jan.	5	Disapp.	*f* Tauri	Lassell Refl.	170	Dark	5 21 20·15	H. T
	5	,,	*f* Tauri	Altaz	100	,,	5 21 19·88	T.
	5	,,	*f* Tauri	N. Eq.	80	,,	5 21 20·22	C.
	5	Reapp.	*f* Tauri	N. Eq.	80	Bright	6 24 33·88	C.
	6	,,	θ^2 Tauri	Altaz.	100	,,	8 54 22·36	R. W.
	6	,,	θ^1 Tauri	Altaz.	100	,,	9 2 18·86	R. W.
	6 (*a*)	Disapp.	Aldebaran	E. Eq.	210	Dark	12 16 24·53	A. D.
	6 (*b*)	,,	Aldebaran	Altaz.	100	,,	12 24·19	R. W.
	12	Reapp.	45 Leonis	E. Eq.	140	,,	31 5·64	A. D.
	12	Disapp.	ρ Leonis	E. Eq.	140	Bright	41 29 41·02	A. D.
	12	Reapp.	ρ Leonis	E. Eq.	140	Dark	12 30 15 02	A. D.
	28	Disapp.	4 Ceti	E. Eq.	140	,,	7 15 40·91	A. D.
	28	,,	4 Ceti	Altaz.	100	,,	7 15 40·79	S. D.
	28	,,	5 Ceti	E. Eq.	140	,,	7 42 3·78	A. D.
	28	,,	5 Ceti	Altaz.	100	,,	7 42 4·38	S. D.
Feb.	2 (*c*)	,,	48 Tauri	E. Eq.	60	,,	13 14 16·33	L.
	6	,,	3 Cancri	Altaz.	100	,,	9 17 15·72	H. T.
	6	,,	3 Cancri	E. Eq.	210	,,	9 17 14 89	L.

Day of Obs.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1887, Mar.	2	Disapp.	Aldebaran	E. Eq.	70	Dark	5 46 56·97	H. T.
	2 (*d*)	,,	Aldebaran	Altaz.	100	,,	5 46 56·75	T.
	2	,,	Aldebaran	Detached Tel. No. 2	65	,,	5 46 56·97	L.
	2 (*e*)	Reapp.	Aldebaran	Lassell finder	30	Bright	6 3 19·76	H. T.
	2 (*f*)	,,	Aldebaran	Altaz.	100	,,	6 3 19·63	T.
	2 (*g*)	,,	Aldebaran	E. Eq.	70	,,	6 3 18·09	L.
	13	,,	γ Libræ	E. Eq.	70	Dark	17 9 45·29	H. T.
	29 (*h*)	Disapp.	θ^1 Tauri	E. Eq.	140	,,	9 16 52·42	T.
	29 (*i*)	,,	θ^2 Tauri	E. Eq.	140	,,	9 25 33·49	T.
Apr.	7 (*k*)	,,	46 Virginis	E. Eq.	140	,,	9 22 24·16	L.
	14 (*l*)	Reapp.	57 Sagittarii	Altaz.	100	,,	16 9 29·40	A. D.
	30	Disapp	54 Cancri	E. Eq.	140	,,	9 35 44 48	H.
	30	,,	o^1 Cancri	E. Eq.	140	,,	12 24 39·84	H.
July	1 (*m*)	,,	η Libræ	E. Eq.	210	,,	9 23 5·00	C.
	1 (*n*)	,,	η Libræ	Altaz.	100	,,	9 23 4·65	L.
Aug.	8	Reapp.	29 Ceti	Altaz.	100	,,	16 5 8·16	L.
	31	Disapp.	45 Capricorni	Altaz.	100	,,	12 14 34·94	A. D.
Sept.	28	,,	42 Aquarii	E. Eq.	210	,,	10 13 9·18	A. D.
Oct.	12	,,	Regulus	E. Eq.	210	Bright	16 44 16·61	H. T.
	12 (*o*)	,,	Regulus	Altaz.	100	,,	16 44 16·66	L.
	12 (*p*)	Reapp.	Regulus	E. Eq.	210	Dark	17 50 38·99	H. T.
	12	,,	Regulus	Altaz.	100	,,	17 50 36·65	L.

Day of Obs.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1887, Oct.	26	Disapp.	70 Aquarii	E. Eq.	210	Dark	7 49 48·82	C.
	28	„	Piazzi 0–60	Altaz.	100	„	11 31 35·43	H. T.
	28	„	Piazzi 0–60	E. Eq.	210	„	11 31 35 82	C.
	31 (*q*)	„	μ Ceti	Cooke Eq.	210	Bright	14 33 7 89	L.
	31 (*r*)	„	μ Ceti	Altaz.	100	„	14 32 55·76	H.
Nov.	6 (*s*)	Reapp.	*g* Geminorum	Altaz.	100	Dark	10 52 14·09	T.
Dec.	27	Disapp.	75 Tauri	Altaz.	100	„	6 26 32·34	B.

Notes.

(*a*) (*b*) Disappearance instantaneous.

(*c*) Observation not considered satisfactory; the counting of the clock-beats interfered with by noise.

(*d*) Sky very foggy. Disappearance instantaneous.

(*e*) No low-power eyepiece for the large telescope could be found, and as there was barely time for the accurate setting in position-angle required for a high power, the reappearance was observed in the finder, a small reflecting telescope of 4·4 inch aperture The reappearance did not seem to be instantaneous. Star appeared bright as compared with the surface of the Moon. Seemed to cling to the limb, and be divided by a projection on the limb, the northern portion of the star being fainter.

(*f*) Star appeared to run along the Moon's limb.

(*g*) Star appeared to run along the Moon's limb for about 19^s; for 5^s it had the appearance of shining from behind some obstacle, which seemed to split the image of the star into two. It did not appear to be quite clear of the Moon's limb till 32^s after the reappearance.

(*h*) Star appeared very faint before the disappearance. (*i*) Star appeared very faint indeed before the disappearance.

(*k*) Slight haze round the Moon. The star appeared to be almost in contact with the rugged bright edge of the Moon at the disappearance.

(*l*) Star very faint when first seen. (*m*) Cloudy, but observation considered satisfactory. (*n*) Star faint; cloudy.

(*o*) Star appeared in contact with the Moon's limb 3^s before the actual disappearance.

(*p*) The star reappeared nearer to the edge of the field than was expected, and seems from L.'s observation (with which it was compared 1^m afterwards) not to have been seen at the first moment of reappearance.

(*q*) The star seemed to come in contact with a prominence on the Moon's limb, and slide down the incline about 3^s before the actual disappearance.

(*r*) Moon very bright; difficult to see the star just before its disappearance behind a roughness on the limb.

(*s*) Star very faint; sky thick.

Phenomena of Jupiter's Satellites.

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1887, April 3	II.	Ecl. D.	Began to fade	E. Eq.	210	10 51 13	10 54 12	A. D.
3	II.		Last seen	,,	,,	10 53 48		,,
8 (*a*)	III.	Occ. R.	Bisection	,,	,,	11 37 30	11 41	H. T.
8	III.		Last contact	,,	,,	11 40 30		,,
14	I.	Occ. R.	First seen	,,	,,	10 9 58		F.
14	I.		Bisection	,,	,,	10 13 13	10 15	,,
14	I.		Last contact	,,	,,	10 16 45		,,
19	II.	Tr. Ing.	First contact	,,	,,	11 2 46	11 6	L.
19	II.		Last contact	,,	,,	11 8 30		,,
20 (*b*)	I.	Tr. Ing.	First contact	,,	140	12 27 53		T.
20	I.		Bisection	,,	,,	12 30 22	12 30	,,
20	I.		Last contact	,,	,,	12 33 52		,,
May 5 (*c*)	II.	Occ. D.	First contact	,,	,,	9 47 42		A. D.
5	II.		Bisection	,,	,,	9 50 21	9 55	,,
5	II.		Last contact	,,	,,	9 54 6		,,

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1887. May 10 (*d*)	III.	Tr. Ing.	First contact	E. Eq.	210	12 44 9	12 47	L.
10	III.		Last contact	,,	,,	12 49 48		,,
14	I.	Occ. D.	Bisection	,,	,,	9 25 32	9 25	A. P.
14	I.		Last contact	,,	,,	9 28 2		,,
14	I.	Ecl. R.	First seen	,,	,,	12 7 19	12 7 16	,,
21 (*e*)	II.	Tr. Ing.	First contact	,,	,,	9 6 29	9 9	A. D.
21	II.		Bisection	,,	,,	9 9 13		,,
21	II.		Last contact	,,	,,	9 11 58		,,
21	III.	Ecl. R.	First seen	,,	,,	10 26 48	10 28 55	,,
21	III.		Full brightness	,,	,,	10 32 30		,,
21 (*f*)	III.		First seen	Altaz.	100	10 29 19		T.
21	I.	Occ. D.	First contact	E. Eq.	210	11 5 10	11 10	A. D.
21	I.		Bisection	,,	,,	11 7 54		,,
21	I.		Last seen	,,	,,	11 11 35		,,
21	II.	Tr. Egr.	First contact	,,	,,	11 38 19	11 42	,,
21	II.		Last contact	,,	,,	11 45 3		,,
June 13	II.	Occ. D.	Bisection	,,	,,	10 48 58	10 49	R. W.
13	II.		Last seen	,,	,,	10 50 49		,,

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1887. June 13	I.		First contact	E. Eq.	210	10 57 41		R. W.
13	I.		Bisection	,,	,,	11 0 7	11 0	,,
13	I.		Last seen	,,	,,	11 1 26		,,
22 (*g*)	III.	Tr. Ing.	First contact	,,	140	9 29 9	9 39	A. D.
22	III.		Last contact	,,	,,	9 41 46		,,
22	II.	Tr. Egr.	First contact	,,	,,	10 20 1		,,
22	II.		Bisection	,,	,,	10 24 2	10 21	,,
22	II.		Last contact	,,	,,	10 28 31		,,
22 (*h*)	I.	Ecl. R.	First seen	,,	,,	10 36 29	10 36 7	,,
22 (*i*)	I.		First seen	Altaz.	100	10 39 39		H.
July 3	III.	Ecl. R.	First seen	,,	,,	10 17 4	10 18 54	T.
7 (*k*)	I.	Tr. Egr.	First contact	,,	,,	10 44 31	10 31	,

Notes.

(*a*) Sky cloudy at time of first contact; last contact observed through passing clouds. (*b*) Sky hazy.
(*c*) *Jupiter* very ill-defined. The observations of first contact and bisection considered unsatisfactory.
(*d*) Sky hazy. Limb of *Jupiter* ill-defined. (*e*) Satellite very faint; sky thick.
(*f*) Satellite very faint. (*g*) *Jupiter's* limb badly defined.
(*h*) Time of full brightness could not be estimated on account of clouds; the time when first seen is considered accurate.
(*i*) Cloudy. (*k*) Satellite hardly visible; planet very low.

Observations of Phenomena of Jupiter's Satellites, at Windsor, New South Wales, in the year 1887. By J. Tebbutt.

Day of Observation.	Satellite.	Phenomena.	Phase.	Aperture of Telescope.	Mag. Power.	Windsor Mean Time of Phase. h m s	Correction to Nautical Almanac. m s
1887, Mar. 17	I.	Ecl. D.	Last seen	8-inch	170	10 25 59·4	+ 0 56·6
25	I.	Tr. Ingr.	Ext. contact	,,	,,	9 59 23·0	
25	I.	,,	Int. contact	,,	,,	10 3 52·3	
25	III.	Ecl. D.	Began to fade	,,	,,	10 59 57·9	
25	III.	,,	Last seen	,,	,,	11 8 28·5	+ 6 14·7
25	III.	Ecl. R.	First seen	,,	,,	12 50 58·9	− 1 24·9
25	III.	,,	Full brightness	,,	,,	12 59 53·0	
April 2	I.	Ecl. D.	Began to fade	4½-inch	130	8 38 53·9	
2	I.	,,	Last seen	,,	,,	8 40 53·1	+ 0 36·3
7	II.	,,	Began to fade	8-inch	170	10 13 39·5	
7	II.	,,	Last seen	,,	,,	10 16 21·0	+ 0 28·2
9	I.	,,	Began to fade	,,	,,	10 32 51·8	
9	I.	,,	Last seen	,,	,,	10 34 47·0	+ 0 56·2
10	I.	Tr. Ingr.	Ext. contact	4½-inch	130	7 56 16·5	
10	I.	,,	Int. contact	,,	,,	8 0 30·8	
10	I.	Tr. Egr.	Int. contact	8-inch	170	10 3 30·2	
10	I.	,,	Ext. contact	,,	,,	10 7 24·6	
23	II.	Tr. Ingr.	Ext. contact	,,	,,	10 13 4·2	

on.	Satellite.	Phenomena.	Phase.	Aperture of Telescope.	Mag. Power.	Windsor Mean Time of Phase. h m s	Corrected to Nautical Almanac. m s
. 23	II.	Tr. Ingr.	Bisection	8-inch	170	10 16 33 7	
23	II.	,,	Int. contact	,,	,,	10 19 33·2	
25	II.	Ecl. R.	First seen	4½-inch	130	7 19 10·3	+ 2 14·5
30	III.	,,	First seen	8-inch	170	8 35 44·7	− 3 2·1
30	III.	,,	Full brightness	,,	,,	8 42 46·1	
y 3	I.	Tr. Ingr.	Ext. contact	,,	,,	7 35 46·2	
3	I.	,,	Bisection	,,	,,	7 37 35·9	
3	I.	,,	Int. contact	,,	,,	7 39 5·6	
7	III.	Occ. D.	First contact	,,	,,	9 19 9·5	
7	III.	,,	Last seen	,,	,,	9 35 6·9	
7	III.	Ecl. R.	First seen	,,	,,	12 33 7·2	− 3 24·6
7	III.	,,	Full brightness	,,	,,	12 46 35·0	
9	I.	Occ. D.	First contact	,	,,	12 9 11·9	
9	I.	,,	Bisection	,,	,,	12 11 11·5	
9	I.	,,	Last seen	,,	,,	12 13 1·2	
9	II.	Ecl. R.	First seen	,,	,,	12 30 29·8	+ 0 35·0
9	II.	,,	Full brightness	,,	,,	12 34 7 7	
10	I.	Tr. Ingr.	Ext. contact	,,	,,	9 20 40·4	
10	I.	,,	Int. contact	,,	,,	9 23 39 9	
11	I.	Ecl. R.	First seen	,,	230	9 13 35·1	− 0 0·7

Day of Observation.	Satellite.	Phenomena.	Phase.	Aperture of Telescope.	Mag. Power.	Windsor Mean Time of Phase h m s	Correction to Nautical Almanac. m s
1887, May 11	I.	Ecl. R.	Full brightness	8-inch	230	9 16 11·2	
25	III.	Tr. Egr.	Bisection	,,	138	7 11 40·6	
25	III.	,,	Ext. contact	,,	,,	7 19 9·4	
25	II.	Tr. Ingr.	Ext. contact	,,	230	8 23 48·6	
25	II.	,,	Bisection	,,	,,	8 24 58·4	
25	II.	,,	Int. contact	,,	,,	8 26 48·1	
25	I.	Occ. D.	First contact	,,	,,	10 7 11·4	
26	I.	Tr. Ingr.	Ext. contact	,,	138	7 17 39·1	
26	I.	,,	Int. contact	,,	,,	7 22 8·4	
June 3	I.	Ecl. R.	First seen	,,	230	9 24 37·4	− 0 6·4
3	I.	,,	Full brightness	,,	,,	9 27 12·9	
3	II.	,,	First seen	,,	,,	9 40 11·3	+ 0 23·5
3	II.	,,	Full brightness	,,	,,	9 43 10·3	
12	I.	,,	First seen	,,	,,	5 47 46·8	+ 0 3·0
12	I.	,,	Full brightness	,,	,,	5 50 50·3	
12	III.	Ecl. D.	Began to fade	,,	138	6 41 21·9	
12	III.	,,	Last seen	,,	,,	6 51 45·1	+ 5 47·3
12	III.	Ecl. R.	First seen	,,	,,	8 22 57·5	− 3 14·3
12	III.	,,	Full brightness	,,	,,	8 33 23·2	
18	I.	Tr. Ingr.	Ext. contact	,,	,,	7 10 38·9	

Day of Observation.	Satellite.	Phenomena.	Phase.	Aperture of Telescope.	Mag. Power.	Windsor Mean Time of Phase.	Correction to Nautical Almanac.
						h m s	m s
1887, June 18	I.	Tr. Ingr.	Bisection	8-inch	138	7 12 38·6	
18	I.	,,	Int. contact	,,	,,	7 15 8·2	
18	I.	Tr. Egr.	Int. contact	,,	,,	9 19 2·5	
18	I.	,,	Bisection	,,	,,	9 23 56·7	
18	I.	,,	Ext. contact	,,	,,	9 26 16·3	
19	III.	Occ. D.	First contact	,,	,,	5 58 20·7	
19	III.	,,	Bisection	,,	,,	6 3 34·8	
19	III.	,,	Last seen	,,	,,	6 6 49·3	
19	II.	Tr. Egr.	Int. contact	,,	,,	7 8 39·0	
19	II.	,,	Bisection	,,	,,	7 13 8·2	
19	II.	,,	Ext. contact	,,	,,	7 16 52·6	
19	I.	Ecl. R.	First seen	,,	,,	7 41 55·4	− 0 16·4
19	I.	,,	Full brightness	,,	,,	7 45 17·8	
19	III.	Occ. R.	First seen	,,	,,	7 58 30·6	
19	III.	,,	Last contact	,,	,,	8 5 29·5	
19	III.	Ecl. D.	Began to fade	,,	,,	10 40 33·6	
19	III.	,,	Last seen	,,	,,	10 52 0·7	+ 6 20·9
25	I.	Tr. Ingr.	Ext. contact	,,	,,	9 1 58·8	
25	I.	,,	Bisection	,,	,,	9 4 18·4	

Day of Observation.	Satellite.	Phenomena.	Phase.	Aperture of Telescope.	Mag. Power.	Windsor Mean Time of Phase. h m s	Correction to Nautical Almanac. m s
1887, June 25	I.	Tr. Ingr.	Int. contact	8-inch	138	9 6 33·1	
26	II.	„	Ext. contact	„	„	7 5 7·7	
26	II.	„	Bisection	„	„	7 6 47·4	
26	II.	„	Int. contact	„	„	7 9 2·0	
26	III.	Occ. D.	First contact	„	„	9 37 42·2	
July 14	III.	Tr. Ingr.	Ext. contact	„	300	7 4 0·5	
14	III.	„	Bisection	„	„	7 8 29·8	
14	III.	„	Int. contact	„	„	7 15 13·6	
14	III.	Tr. Egr.	Bisection	„	230	9 17 38·2	
14	III.	„	Ext. contact	„	„	9 23 7·3	
18	I.	Tr. Ingr.	Ext. contact	„	138	9 10 37·4	
18	I.	„	Bisection	„	„	9 12 47·0	
18	I.	„	Int. contact	„	„	9 15 21·6	
21	II.	Tr. Egr.	Bisection	„	230	6 31 46 8	
21	II.	„	Ext. contact	„	„	6 35 11·2	
25	III.	Ecl. D.	Began to fade	„	„	6 36 28·5	
25	III.	„	Last seen	„	„	6 47 19·7	+ 6 1·9
25	III.	Ecl. R_1	First seen	„	„	8 14 10·1	− 3 1·7
25	III.	„	Full brightness	„	„	8 23 40·6	

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Day of Observation.	Satellite.	Phenomena.	Phase.	Aperture of Telescope.	Mag. Power.	Windsor Mean Time of Phase.	Correction to Nautica Almanac.
						h m s	m
887, July 27	I.	Tr. Egr.	Int. contact	8-inch	138	7 46 46·3	
27	I.	,,	Ext. contact	,,	,,	7 52 15·3	
28	I.	Ecl. R.	First seen	,,	,,	6 12 23·6	− 0 17·2
28	I.	,,	Full brightness	,,	,,	6 14 1·3	
28	II.	Tr. Ingr.	Ext. contact	,,	230	6 31 48·4	
28	II.	,,	Bisection	,,	,,	6 33 28·1	
28	II.	,,	Int. contact	,,	,,	6 35 27·8	
28	II.	Tr. Egr.	Int. contact	,,	138	9 4 3·0	
28	II.	,,	Bisection	,,	,,	9 7 32·4	
28	II.	,,	Ext. contact	,,	,,	9 11 16·8	
30	II.	Ecl. R.	First seen	,,	,,	6 37 40·8	+ 0 15·0
30	II.	,,	Full brightness	,,	,,	6 42 26·5	
Aug. 1	III.	Occ. R.	Last contact	,,	230	7 30 15·5	
3	I.	Tr. Ingr.	Ext. contact	,,	138	7 32 33·2	
3	I.	,,	Bisection	,,	,,	7 34 42·8	
3	I.	,,	Int. contact	,,	,,	7 37 12·4	
6	II.	Ecl. R.	First seen	$4\frac{1}{2}$-inch	120	9 15 11·5	+ 0 51 7
6	II.	,,	Full brightness	,,	,,	9 17 55·0	
Sept. 12	I.	,,	First seen	8-inch	230	6 38 15·0	− 0 4·8
12	I.	,,	Full brightness	,,	,,	6 40 59·5	

Remarks.

March 17.—Sky clear; slight boiling of the planet's limb.

March 25.—Sky clear. Bad definition and images unsteady at ingress. Definition somewhat improved during the eclipse. Satellite suspected at $12^h\ 50^m\ 31^s{\cdot}5$. Reappearance difficult to observe in consequence of the satellite's proximity to the limb.

April 2.—Clear sky and good definition. Good observation.

April 7.—A very thin cloud passed over at the critical time, but did not appear to dim the satellites. Excellent definition. Satellite suspected again at $10^h\ 16^m\ 38^s{\cdot}6$.

April 9.—Sky beautifully clear, but the Moon very bright and near the planet.

April 10.—Definition pretty good throughout.

April 23.—Definition pretty good, but images unsteady.

April 25.—Reappearance noted just as the planet was emerging from a cloud, and satellite then tolerably well seen.

April 30.—Planet very slightly dimmed by faint cloud when satellite first seen; satellite suspected a few seconds earlier. Reappearance very slow, and full brightness difficult to determine.

May 3.—Definition not good.

May 7.—Definition fairly good. Disappearance very gradual, owing to the inclination of the planet's limb. Sky beautifully clear at the reappearance, and the definition fairly good. Full Moon distant a few degrees from the planet. The recovery of the satellite's light was very gradual, and at greatest brightness it slightly surpassed satellite I. near it.

May 9.—Definition pretty good at the occultation, and better at the eclipse. The observation of reappearance was rather late and the full brightness could not be well determined.

May 10.—Definition very bad.

May 11.—Steadiness and definition satisfactory. Satellite suspected at $9^h\ 13^m\ 26^s{\cdot}6$. Full brightness difficult to determine.

May 25.—Definition fair at ingress of III. Images steady and well defined at ingress of II. Planet faint and badly defined at occultation of I.

May 26.—Fair definition.

June 3.—Sky beautiful and the images steady and well defined. Planet a few degrees distant from the Moon.

June 12.—Beautifully clear, but the definition at the eclipse of I. was not good. Observation probably rather late. Images rather tremulous at disappearance of III. III. lost about half its light by $6^h\ 45^m\ 41^s{\cdot}2$, and was suspected at $6^h\ 52^m\ 0^s{\cdot}1$. Definition better at reappearance.

June 18.—Definition better at ingress than at egress; the internal contact at egress was probably observed too early.

June 19.—Total disappearance of III. in occultation; doubtful in consequence of a passing cloud. Planet and satellite faint at egress of II. Sky beautifully clear at reappearance of I., and images bright, steady, and well defined. Definition not so good at the last contact at reappearance of III. Sky still clear at disappearance of III. and images steady and well defined. Satellite glimpsed again at $10^h\ 52^m\ 26^s{\cdot}6$.

June 25.—Good definition.

June 26.—Sky clear and definition good at ingress of II. Clouds prevented further observation of III.

July 14.—Definition fairly good at the external but not so good at the internal contact at ingress. Planet faint and badly defined at egress.

July 18.—Definition good at the external contact, but bad at the other phases. Satellite IV., which was about in conjunction with the planet's centre, was remarkably dull and faint.

July 21.—Definition pretty good.

July 25.—Definition pretty good at both phases, but Moon near planet.

July 27.—Definition bad at internal but better at external contact.
July 28.—Sky beautifully clear. Definition fair at reappearance of I., but much disturbed during the other observations.
July 30.—Sky beautifully clear, and good definition.
Aug. 1.—Definition pretty good.
Aug. 3.—Fair definition.
Aug. 6.—Sky beautifully clear, and definition good; but satellite rather conspicuous when first seen.
Sept. 12.—Sky clear, and definition good; the twilight, however, had not quite disappeared.

Windsor, N.S. Wales:
1887, *November* 28.

Ephemeris of the Satellites of Mars, 1888. By A. Marth.

The values of the longitude of the node N and of the inclination J of the orbit of *Deimos*, in reference to the plane parallel to the Earth's equator, which have been employed in the following ephemeris are

$$N = 49^\circ\,549, \qquad J = 36^\circ{\cdot}029.$$

The assumed proportion of the mass of the Sun to that of *Mars* is

$$\odot = 3095000.$$

The orbital longitude of *Deimos*, reckoned from the node, is

$$u_2 = 145^\circ{\cdot}80 + 285^\circ{\cdot}1620\,(t - t_0),$$

the epoch t_0 being 1888, April, 12·0 Gr.

Phobos is assumed to move in the plane of the orbit of *Deimos*, and its longitude is taken to be

$$u_1 = 101^\circ{\cdot}16 + 1128^\circ{\cdot}8490\,(t - t_0),$$

its value being somewhat uncertain, as no observations of the satellite made during the last opposition have become known.

a, b, major and minor semi-axes of the apparent ellipses described by the satellites.

P, position-angle of the minor axes in the direction of superior conjunction.

U + 180° and B, areocentric longitude and latitude of the Earth referred to the plane of the orbit of *Deimos*, and reckoned from the node.

$u - U$ longitudes of the satellites, reckoned in their orbits from the points which are in superior conjunction with the planet's centre.

		Phobos.			*Deimos.*					
enwich Noon. 888.		a_1	b_1	u_1-U	a_2	b_2	u_2-U	P	U	B
ar.	15	18″·14	+6″·10	0″·72	45″·41	+15″·26	272°·06	36°·29	168°·03	+19°·64
	16	18·30	6·16	49·76	45·80	15·42	197·38	36·26	167·88	19·68
	17	18·46	6·23	98·81	46·19	15·59	122·72	36·23	167·72	19·73
	18	18·62	6·30	147·88	46·58	15·76	48·07	36·20	167·54	19·78
	19	18·77	6·37	196·95	46·96	15·94	333·43	36·16	167·35	19·84
	20	18·92	6·44	246·03	47·34	16·11	258·80	36·12	167·15	19·90
	21	19·07	6·51	295·13	47·72	16·29	184·18	36·08	166·93	19·96
	22	19·22	6·58	344·24	48·08	16·47	109·58	36·03	166·71	20·03
	23	19·36	6·65	33·36	48·44	16·65	34·99	35·98	166·47	20·10
	24	19·50	6·73	82·49	48·79	16·83	320·41	35·93	166·22	20·18
	25	19·64	6·81	131·63	49·14	17·01	245·84	35·88	165·96	20·26
	26	19·77	6·88	180·78	49·48	17·19	171·28	35·82	165·69	20·34
	27	19·90	6·95	229·94	49·81	17·38	96·73	35·76	165·40	20·42
	28	20·03	7·02	279·11	50·12	17·57	22·19	35·69	165·10	20·51
	29	20·15	7·09	328·29	50·43	17·75	307·67	35·62	164·80	20·60
	30	20·27	7·17	17·48	50·72	17·93	233·15	35·55	164·49	20·70
	31	20·38	7·24	66·68	51·01	18·11	158·64	35·48	164·17	20·80
pril	1	20·49	+7·31	115·88	51·28	+18·29	84·14	35·40	163·83	+20·90
	2	20·59	7·38	165·09	51·54	18·47	9·65	35·32	163·49	21·00
	3	20·69	7·45	214·31	51·78	18·65	295·17	35·24	163·14	21·10
	4	20·78	7·52	263·54	52·01	18·82	220·69	35·15	162·78	21·21
	5	20·87	7·59	312·77	52·22	18·99	146·22	35·06	162·42	21·32
	6	20·95	7·65	2·00	52·42	19·15	71·76	34·97	162·05	21·43
	7	21·02	7·72	51·24	52·61	19·31	357·30	34·88	161·67	21·54
	8	21·09	7·78	100·48	52·78	19·47	282·85	34·78	161·29	21·65
	9	21·15	7·84	149·73	52·93	19·62	208·40	34·68	160·90	21·76
	10	21·20	7·90	198·98	53·06	19·77	133·96	34·57	160·51	21·88
	11	21·25	7·96	248·23	53·17	19·92	59·51	34·47	160·12	22·00
	12	21·29	8·01	297·48	53·27	20·05	345·07	34·36	159·73	22·11
	13	21·32	8·06	346·73	53·35	20·18	270·63	34·25	159·34	22·23
	14	21·34	8·11	35·98	53·41	20·30	196·19	34·14	158·94	22·34
	15	21·36	8·16	85·23	53·45	20·41	121·75	34·03	158·54	22·46
	16	21·37	+8·20	134·47	53·47	+20·52	47·30	33·92	158·15	+22·57
	17	21·37	8·24	183·71	53·48	20·62	332·85	33·81	157·76	22·68
	18	21·37	8·28	232·94	53·47	20·72	258·40	33·69	157·37	22·80
	19	21·36	8·31	282·17	53·44	20·80	183·95	33·58	156·99	22·91
	20	21·34	8·34	331·40	53·39	20·88	109·49	33·46	156·61	23·02
	21	21·31	8·37	20·62	53·33	20·95	35·03	33·35	156·23	23·13
	22	21·28	+8·39	69·83	53·25	+21·01	320·56	33·23	155·86	+23·24

Greenwich Noon. 1888.	*Phobos.* a_1	b_1	u_1-U	*Deimos.* a_2	b_2	u_2-U	P	U	B
	″	″	″	″	″	°	°	°	°
April 23	21·24	+ 8·41	119·03	53·15	+ 21·06	246·08	33·12	155·50	+ 23·34
24	21·20	8·43	168·23	53·04	21·10	171·59	33·01	155·15	23·45
25	21 15	8·45	217·42	52·91	21·14	97·10	32·90	154·80	23·55
26	21·09	8·46	266·59	52·77	21 17	22·60	32·79	154·46	23·65
27	21·03	8·47	315·76	52·61	21·19	308 09	32 68	154·13	23·75
28	20 96	8·47	4·92	52·44	21·20	233·56	32 58	153·81	23·84
29	20·88	8·47	54·06	52·26	21·20	159·03	32·48	153·50	23·94
30	20·80	8·47	103·19	52·06	21·20	84·49	32·38	153 20	24·03
May 1	20·72	+ 8·47	152·31	51·85	+ 21·19	9 94	32·28	152·92	+ 24 12
2	20·63	8·46	201·42	51·63	21·17	295 37	32·19	152·64	24·21
3	20·54	8·45	250·52	51·40	21·14	220·79	32·10	152·38	24·29
4	20·44	8·44	299·60	51·15	21 11	146·20	32 02	152·13	24·37
5	20·34	8·42	348·67	50·90	21·07	71·59	31·94	151·89	24·45
6	20 24	8·40	37·72	50·64	21·02	356·98	31·86	151·66	24·53
7	20·13	8·38	86·76	50·37	20·97	282·35	31·78	151·45	24·61
8	20·02	8·36	135·78	50·09	20·91	207·70	31·71	151·25	24 68
9	19·90	8·33	184·79	49·80	20·85	133·04	31·65	151·06	24·75
10	19·78	8·30	233·79	49·51	20·78	58 37	31·59	150·89	24·82
11	19·66	8·27	282·77	49·21	20·71	343·68	31·54	150·74	24·89
12	19·54	8·24	331·73	48·91	20·63	268·98	31·49	150·60	24·95
13	19·42	8·21	20·68	48·60	20·55	194·26	31·44	150·47	25 01
14	19·30	8·17	69·61	48·29	20 46	119·53	31·40	150·35	25 07
15	19·17	8·14	118·53	47·97	20·37	44·78	31 37	150·25	25·13
16	19·04	8·10	167·44	47·65	20·27	330·02	31·34	150·17	25·18
17	18·91	8·06	216·33	47·33	20·17	255·24	31·32	150 10	25·23
18	18·78	8·02	265·20	47·00	20·07	180·45	31·30	150·05	25·28
19	18·65	7·98	314·06	46·67	19·96	105·64	31·29	150·01	25·33
20	18·52	7·93	2·90	46·34	19·85	30·82	31·28	149·98	25·37
21	18·39	7 89	51·72	46·01	19·74	315·99	31·28	149·97	25·41
22	18·25	7·84	100·53	45·68	19·63	241·14	31·28	149·97	25·45
23	18·12	7·80	149·33	45·35	19 51	166·27	31·29	149·99	25·49
24	17·99	7·75	198·11	45·02	19·39	91·39	31·30	150 02	25·52
25	17·86	7·70	246·88	44·68	19·27	16·50	31·32	150·07	25·55
26	17·72	7·65	295·64	44·35	19·15	301·60	31·34	150·13	25·58
27	17·59	7·60	344·38	44·02	19·03	226 68	31·37	150·20	25·61
28	17·46	7·55	33·11	43·69	18·90	151·75	31·40	150·29	25·63
29	17·33	7·50	81·82	43·37	18·78	76 80	31·44	150·39	25·66
30	17·20	+ 7·45	130·52	43·04	+ 18 65	1·84	31·48	150·50	+ 25·68

These values are to be interpolated directly for the times for which the positions of the satellites are required, the equation of light having already been taken into account in the ephemeris. The position-angles p and distances s are then found by means of the formulæ

$$s \sin (p - \mathrm{P}) = a \sin (u - \mathrm{U})$$
$$s \cos (p - \mathrm{P}) = b \cos (u - \mathrm{U}).$$

The satellites move in the direction of increasing position-angles, and will be at their greatest eastern and western elongations (e in position P+90° and w in position P−90°) about the following Greenwich mean times:—

	Phobos.	*Deimos.*		*Phobos.*	*Deimos.*
1888.	h	h	1888.	h	h
Mar. 15	13·4 *w*	15·0 *e*	Apr. 12	10·9 *e*	8·8 *e*
16	12·3 *w*	21·2 *e*	13	9·8 *e*	15·1 *e*
17	11·3 *w*	12·4 *w*	14	8·8 *e*	6·2 *w*
18	14·1 *e*	18·7 *w*	15	11·6 *w*	12·5 *w*
19	13·0 *e*	9·8 *e*	16	10·5 *w*	18·7 *w*
20	12·0 *e*	16·1 *e*	17	9·5 *w*	9·8 *e*
21	10·9 *e*	7·2 *w*	18	8·4 *w*	16·1 *e*
22	13·7 *w*	13 5 *w*	19	11·2 *e*	7·2 *w*
23	12·7 *w*	19·8 *w*	20	10·2 *e*	13·5 *w*
24	11·6 *w*	10·9 *e*	21	9·1 *e*	19·7 *w*
25	10·6 *w*	17·2 *e*	22	8·1 *e*	10·9 *e*
26	13·4 *e*	8·3 *w*	23	10·9 *w*	17·1 *e*
27	12·3 *e*	14·6 *w*	24	9·8 *w*	8·3 *w*
28	11·3 *e*	20·8 *w*	25	8·8 *w*	14·5 *w*
29	10·2 *e*	12·0 *e*	26	11·5 *e*	20·8 *w*
30	13·0 *w*	18·2 *e*	27	10·5 *e*	11·9 *e*
31	12·0 *w*	9·4 *w*	28	9·5 *e*	18·2 *e*
Apr. 1	10·9 *w*	15·6 *w*	29	8·4 *e*	9·3 *w*
2	9·9 *w*	6·7 *e*	30	11·2 *w*	15·6 *w*
3	12 7 *e*	13·0 *e*	May 1	10·2 *w*	6·7 *e*
4	11·6 *e*	19·3 *e*	2	9·1 *w*	13·0 *e*
5	10·6 *e*	10·4 *w*	3	8·1 *w*	19·3 *e*
6	9·5 *e*	16·7 *w*	4	10·8 *e*	10·4 *w*
7	12·3 *w*	7·8 *e*	5	9·8 *e*	16 7 *w*
8	11·3 *w*	14·0 *e*	6	8 8 *e*	7·8 *e*
9	10·2 *w*	20·3 *e*	7	11·5 *w*	14·1 *e*
10	9·2 *w*	11 4 *w*	8	10·5 *w*	5·2 *w*
11	11·9 *e*	17·7 *w*	9	9·5 *w*	11·5 *w*

	Phobos.	*Deimos.*			*Phobos.*	*Deimos.*
1888.	h	h	h	1888	h	h	h
May 10	8·4 *w*	12·2 *e*	17·8 *w*	May 19	10·5 *e*	14·4 *w*	13·8 *w*
11	11·2 *e*	15·0 *w*	8·9 *e*	20	9·5 *e*	13·3 *w*	5·0 *e*
12	10·2 *e*	14·0 *w*	15·2 *e*	21	8·5 *e*	12·3 *w*	11·3 *e*
13	9·1 *e*	13·0 *w*	6·4 *w*	22	11·3 *w*	15·1 *e*	17·6 *e*
14	8·1 *e*	11·9 *w*	12·7 *w*	23	10·2 *w*	14·0 *e*	8·7 *w*
15	10·9 *w*	14·7 *e*	18·9 *w*	24	9·2 *w*	13·0 *e*	15·0 *w*
16	9·8 *w*	13·7 *e*	10·1 *e*	25	8·1 *w*	12·0 *e*	6·2 *e*
17	8·8 *w*	12·6 *e*	16·4 *e*	26	7·1 *w*	10·9 *e*	12·5 *e*
18	7·8 *w*	11·6 *e*	7·5 *w*	27	9·9 *e*	13·7 *w*	18·8 *e*

As *Deimos* has been observed with the 15-inch refractor of Harvard College on January 10, 1880, when the log. of the light-ratio of *Mars* was only 9·530 (corresponding to that of March 1 and June 13, 1888), there should be no difficulty of securing at least a few observations of both satellites by the more powerful instruments which are at present available.

Ephemeris of the Satellites of Uranus, 1888. By A. Marth.

	Ariel.				*Umbriel.*				
Greenwich, Noon.	a_1	b_1	u_1-U	Diff.	a_2	b_2	u_2-U	Diff.	P
1888.	″	″	°	°	″	″	°	°	°
Feb. 22	14·99	+7·58	238·59	1428·38	20·88	+10·56	94·65	868·69	283·677
Mar. 3	15·08	7·56	226·97	·36	21·01	10·53	243·34	·66	283·735
13	15·15	7·51	215·33	·33	21·11	10·46	32·00	·65	283·802
23	15·20	7·44	203·66	·30	21·18	10·36	180·65	·62	283·874
Apr. 2	15·22	7·35	191·96	·27	21·20	10·24	329·27	·61	283·947
12	15·21	7·25	180·23	·26	21·20	10·10	117·88	·60	284·019
22	15·18	7·14	168·49	·24	21·15	9·95	266·48	·60	·086
May 2	15·13	+7·02	156·73	·22	21·07	+9·79	55·08	·59	·146
12	15·05	6·91	144·95	·22	20·96	9·63	203·67	·59	·196
22	14·95	6·80	133·17	·22	20·83	9·48	352·26	·59	·235
June 1	14·84	6·71	121·39	·22	20·67	9·34	140·85	·60	·262
11	14·72	6·62	109·61	·23	20·50	9·23	289·45	·61	·277
21	14·59	6·56	97·84	·23	20·32	9·13	78·06	·62	·279
July 1	14·45	6·51	86·07	1428·25	20·13	9·07	226·68	868·64	·267
11	14·32	+6·48	74·32		19·95	+9·03	15·32		284·242

	Titania.				*Oberon.*				
	a_3	b_3	u_3-U	Diff.	a_4	b_4	u_4-U	U	B
1888.	"	"	°	°	"	"	°	°	°
Feb. 22	34·26	+17·31	343·82	413·48	45·81	+23·15	147·18	1·726	+30·36
Mar. 3	34·47	17·26	37·30	·46	46·09	23·09	54·53	1·783	30·06
13	34·63	17·16	90·76	·45	46·31	22·94	321·87	1·849	29·70
23	34·73	17·00	144·21	·45	46·45	22·73	229·20	1·921	29·30
Apr. 2	34·78	16·80	197·66	·44	46·51	22·47	136·52	1·995	28·88
12	34·77	16·57	251·10	·43	46·49	22·16	43·84	2·068	28·46
22	34·69	16·31	304·53	·44	46·39	21·82	311·16	2·136	28·05
May 2	34·56	+16·05	357·97	·44	46·22	+21·46	218·48	2·197	+27·67
12	34·38	15·79	51·41	·45	45·98	21·12	125·81	2·249	27·34
22	34·16	15·54	104·86	·45	45·68	20·79	33·15	2·289	27·07
June 1	33·91	15·32	158·31	·46	45·34	20·49	300·50	2·316	26·87
11	33·62	15·13	211·77	·48	44·97	20·24	207·86	2·329	26·75
21	33·33	14·98	265·25	·49	44·57	20·04	115·23	2·326	26·71
July 1	33·03	14·87	318·74	413·50	44·17	19·89	22·61	2·308	26·77
11	32·73	+14·81	12·24		43·77	+19·80	290·01	2·278	+26·91

The notation is the same as in the ephemeris of the satellites of *Mars*.

The four satellites of *Uranus* are assumed to move in the same plane, the ascending node N and inclination J of which in reference to the celestial equator of 1880·0 are assumed to have the values

$$N = 165°·770; \quad J = 75°·210.$$

The satellites move in the direction of increasing position-angles, and will be at their greatest elongations (N. in position-angle P+90°, S. in position P−90°) and at their conjunctions (superior conjunction in position P, inferior conjunction in position P−180°) with the centre of the planet at the following Greenwich mean times :—

Ariel.

	N. Elong.		S. Elong.			N. Elong.		S. Elong.			N. Elong.		S. Elong.	
1888.	h		h			h		h			h		h	
Feb.	26	0·0	27	6·3	Mar.	19	16·4	20	22·7	Apr.	11	8·8	12	15·1
	28	12·5	28	18·7		22	4·9	23	11·1		13	21·3	15	3·6
Mar.	2	1·0	3	7·2		24	17·4	25	23·6		16	9·8	17	16·1
	4	13·5	5	19·7		27	5·9	28	12·1		18	22·3	20	4·6
	7	2·0	8	8·2		29	18·4	31	0·6		21	10·8	22	17·1
	9	14·5	10	20·7	Apr.	1	6·9	2	13·1		23	23·3	25	5·5
	12	2·9	13	9·2		3	19·4	5	1·6		26	11·8	27	18·0
	14	15·4	15	21·7		6	7·9	7	14·1		29	0·3	30	6·5
	17	3·9	18	10·2		8	20·3	10	2·6	May	1	12·8	2	19·0

1888.	N. Elong. h	S. Elong. h
May 4	1·3	5 7·5
6	13·8	7 20·0
9	2·3	10 8·5
11	14·8	12 21·0
14	3 3	15 9·5
16	15·8	17 22·0
19	4·2	20 10·5
21	16·7	22 23·0
24	5 2	25 11·5

	N. Elong. h	S. Elong. h
May 26	17·7	28 0·0
29	6·2	30 12·5
31	18·7	Ju. 2 1·0
June 3	7·2	4 13·5
5	19·7	7 2·0
8	8·2	9 14·5
10	20·7	12 3·0
13	9·2	14 15·4
15	21·7	17 3·9

	N. Elong. h	S. Elong. h
June 18	10·2	19 16·4
20	22·7	22 4·9
23	11·2	24 17·4
25	23·7	27 5·9
28	12·2	29 18·4
July 1	0·7	2 6·9
3	13·2	4 19·4
6	1·6	7 7·9
8	14·1	9 20·4

Umbriel.

Feb. 26	2·2	28	3·9
Mar. 1	5·6	3	7·4
5	9·1	7	10·8
9	12·6	11	14·3
13	16·0	15	17·8
17	19·5	19	21·2
21	23·0	24	0·7
26	2·4	28	4·2
30	5·9	Ap. 1	7·6
Apr. 3	9·4	1	11·1
7	12·8	9	14·6

Apr. 11	16·3	13	18·0
15	19·8	17	21·5
19	23·2	22	1·0
24	2·7	26	4·4
28	6·2	30	7·9
May 2	9·6	4	11·4
6	13·1	8	14·9
10	16·6	12	18·3
14	20·1	16	21·8
18	23·5	21	1·3
23	3·0	25	4·7

May 27	6·5	29	8·2
31	9·9	Ju. 2	11·7
June 4	13·4	6	15·2
8	16·9	10	18·6
12	20·4	14	22·1
16	23·8	19	1·6
21	3·3	23	5·0
25	6·8	27	8·5
29	10·2	Jy. 1	12·0
July 3	13·7	5	15·4
7	17·2	9	18·9

Titania.

1888.	h		1888.	h		1888.	h		1888.	h	
Feb. 22	9·4	sup.	Mar. 28	5·3		May 2	1·2	sup.	June 5	21·1	
24	13·6	N.	30	9·5		4	5·4	N.	8	1·3	
26	17·9	inf.	Apr. 1	13·7		6	9·7	inf.	10	5·6	
28	22·1	S.	3	18·0		8	13·9	S.	12	9·8	
Mar. 2	2·4	sup.	5	22·2		10	18·2	sup.	14	14·0	
4	6·6	N.	8	2·5		12	22·4	N.	16	18·3	
6	10·8	inf.	10	6·7		15	2·6	inf.	18	22·5	
8	15·1	S.	12	11·0		17	6·9	S.	21	2·8	
10	19·3	sup.	14	15·2		19	11·1	sup.	23	7·0	
12	23·6	N.	16	19·5		21	15·4	N.	25	11·2	
15	3·8	inf.	18	23·7		23	19·6	inf.	27	15·5	
17	8·0	S.	21	4·0		25	23·9	S.	29	19·7	
19	12·3	sup.	23	8·2		28	4·1	sup.	July 1	23·9	
21	16·5	N.	25	12·4		30	8·3	N.	4	4·2	
23	20·8	inf.	27	16·7	June	1	12·6	inf.	6	8·4	
26	1·0	S.	29	20·9		3	16·8	S.	8	12·7	

Oberon.

1888.	h			h			h			h.
Feb. 16	11·9	sup.	Mar. 27	21·4	May 7	7·0	sup.	June 16	16·6
19	20·7	N.	31	6·2	10	15·8	N.	20	1 4
23	5·5	inf.	Apr. 3	15·0	14	0·6	inf.	23	10·1
26	14·3	S.	6	23·8	17	9·4	S.	26	18·9
29	23·0	sup.	10	8·6	20	18·2	sup.	30	3·7
Mar. 4	7·8	N.	13	17·4	24	3·0	N.	July 3	12·5
7	16·6	inf.	17	2·2	27	11·8	inf.	6	21·3
11	1·4	S.	20	11·0	30	20·6	S.	10	6·0
14	10·2	sup.	23	19·8	June 3	5·4	sup.		
17	19·0	N.	27	4·7	6	14·2	N.		
21	3·8	inf.	30	30·5	9	23·0	inf.		
24	12·6	S.	May 3	22·3	13	7·8	S.		

Titania and *Oberon* will appear in a line with the centre of the planet at the following times:—

In opposite directions of the centre—

	h		h		h
Feb. 20	20·7	Apr. 10	3·2	May 29	9·9
Mar. 16	11·9	May 4	18·5	June 23	1·2

And in the same direction from the centre—

	h		h		h
Mar. 4	4·3	Apr. 22	10·9	June 10	17·6
28	19·6	May 17	2·2	July 5	8·9

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. FEBRUARY 10, 1888. No. 4

J. W. L. GLAISHER, Sc.D., F.R.S., President, in the Chair.

The Rev. John Mackenzie Bacon, Coldash, Newbury, Berks;
John Henry Brown, 6 Cambridge Road, Brighton; and
The Rev. W. R. Waugh, The Manse, Portland, Dorset,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

John Edmund Drower, Surveyor, May Trees, Endlesham Road, Balham (proposed by A. A. Common);

George James Newbegin, Thorpe St. Andrew, Norwich (proposed by Philip E. Sewell);

George William Read, F.R.G.S., Master Mariner, Broad Street, Penrhyn, Cornwall (proposed by Captain H. Toynbee).

REPORT OF THE COUNCIL TO THE SIXTY-EIGHTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1886	225	371	3	599	49	1	649
Since elected	+5	+16	...	...	+1	...	...
Deceased	−5	−7	...	...	−2	...	...
Resigned	...	−12	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...
Removals	+1	−1	...	...	...	...	...
December 31, 1887	226	365	3	594	48	1	643

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, Jan. 1, 1887:—						
Balance at Bankers', as per pass book ...	434	2	9			
„ on Suspense Account	2	2	0			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	21	6	0			
„ in hand of Assistant Secretary on Petty Cash Account	1	18	3			
				459	9	0
Half-year's dividend on £7,500 Consols	108	15	0			
„ „ £5,700 New 3 per Cent. Stock	82	13	0			
„ „ £7,500 Consols	109	4	5			
„ „ £5,700 New 3 per Cent. Stock	83	0	2			
Three Quarterly Dividends on £500 Metropolitan Stock	10	18	2			
One Dividend on £750 Metropolitan Stock ...	5	9	3			
				400	0	0
Received on account of Subscriptions:						
Arrears	189	0	0			
249 Annual Contributions for 1887	522	18	0			
1 „ Contribution 1888	2	2	0			
21 Admission Fees	44	2	0			
18 First Contributions	26	5	0			
				784	7	0
Composition Fees				84	0	0
Sales of Publications:						
At Williams and Norgate's, 1886	37	15	10			
At Society's Rooms, 1887	32	0	6			
				69	16	4
				£1,797	12	4

Audited and found correct, Jan. 11, 1888.

RICHARD INWARDS.
HERBERT SADLER.
ROBERT BRYANT.

Astronomical Society, from Jan. 1 to Dec. 31, 1887.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	225	0	0			
,, ,, for assistance in editing Society's Publications ...	50	0	0			
				275	0	0
Income Tax and House Duty				13	2	6
Fire Insurance				7	16	6
Printing	420	19	6			
Engraving and Lithography	13	15	0			
Computation of Ephemerides in *Monthly Notices* ...	50	0	0			
Dr. Dreyer, Computations for Catalogue of Nebulæ	20	0	0			
				504	14	6
Turnor and Horrox Funds: purchases for Library	32	12	10			
Binding Books in Library	39	17	7			
				72	10	5
Purchase of 6-inch Simms Telescope				25	0	0
Photograph of Members of Paris Photographic Conference				4	4	0
House Expenses	34	4	10			
Wages	31	16	0			
Postage, &c.	66	11	11			
Carriage of Parcels	1	12	9			
Stationery and Office Expenses	7	2	7			
Expenses of Meetings	22	10	0			
Coals and Gas	58	16	6			
Linoleum for Meeting Room	13	17	2			
Sundry Fittings and Repairs	10	6	5			
Battery, &c. for Time Signal, and Rental of Wire	10	7	0			
Sundries	7	3	10			
				264	9	0
Jubilee Address to the Queen, engrossing and illuminating	10	10	0			
Seal, &c. for ditto, Wyons	2	2	6			
				12	12	6
Mrs. Jackson Gwilt's Annuity				8	19	0
Lee Fund				5	0	0
Purchase of £250 Metropolitan Stock at 101⅛, including brokerage				253	2	6
Bankers' Deductions on Cheques				0	1	3
Balances, Dec. 31, 1887:—						
Balance at Bankers', as per pass book ...	327	14	1			
,, on Suspense Account	2	2	0			
,, in hand of Assistant Secretary on account of Turnor and Horrox Funds ...	5	19	8			
,, in hand of Assistant Secretary on Petty Cash Account	15	4	5			
				351	0	2
				£1,797	12	4
					0	2

Assets and Present Property of the Society, Jan. 1, 1888.

	£	s.	d.	£	s.	d.
Balances, Dec. 31, 1887:—						
Balance at Bankers', as per pass book, including an amount of £45 7*s.* 3*d.*, being the accumulated interest of the Lee Fund,	327	14	1			
„ on Suspense Account	2	2	0			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	5	19	8			
„ in hand of Assistant Secretary on Petty Cash account	15	4	5			
				351	0	2
Due on account of Subscriptions:						
12 Contributions of 3 years' standing ...	75	12	0			
33 „ 2 „ ...	138	12	0			
70 „ 1 year's standing ...	147	0	0			
2 Admission Fees and First Contributions ...	6	6	0			
	367	10	0			
Less 1 Contribution paid in advance ...	2	2	0			
				365	8	0
Due from Messrs. Williams and Norgate for sales of Publications during 1887				7	19	0

£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

£5,700 New 3 per Cent. Stock, including Mrs. Jackson Gwilt's gift (£300).

£750 Metropolitan Consolidated Stock.

Astronomical and other Manuscripts, Books, Prints, Instruments; and Furniture.

Unsold Publications of the Society.

Two Gold Medals.

Report of the Auditors.

We have examined the Treasurer's accounts, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1887, including the balance at the bankers', amounted to 351*l.* 0*s.* 2*d.*

The funded property of the Society has been increased by the purchase of 250*l.* metropolitan consolidated stock, thus leaving the Society's funds augmented by 141*l.* 11*s.* 2*d.* since the previous year.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid upon the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
ROBERT BRYANT,
HERBERT SADLER.

February 10, 1888.

Stock in hand of volumes of the *Memoirs* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXIX.	409	...
I. Part 2	43	...	XXX.	159	1
II. Part 1	56	...	XXXI.	143	...
II. Part 2	21	...	XXXII.	154	1
III. Part 1	67	1	XXXIII.	164	...
III. Part 2	86	1	XXXIV.	164	4
IV. Part 1	80	3	XXXV.	108	6
IV. Part 2	92	3	XXXVI.	198	10
V.	106	4	XXXVII. Part 1	339	8
VI.	125	3	XXXVII. Part 2	287	8
VII.	145	3	XXXVIII.	276	1
VIII.	127	3	XXXIX. Part 1	248	4
IX.	134	3	XXXIX. Part 2	253	3
X.	146	...	XL.	268	1
XI.	154	...	XLI.	413	1
XII.	159	...	XLII.	238	4
XIII.	163	...	XLIII.	242	1
XIV.	370	3	XLIV.	223	1
XV.	140	...	XLV.	258	1
XVI.	165	...	XLVI.	248	3
XVII.	147	1	XLVII. Part 1	3	...
XVIII.	146	...	XLVII. Part 2	19	...
XIX.	152	...	XLVII. Part 3	2	...
XX.	142	...	XLVII. Part 4	10	...
XXI. Part 1	314	...	XLVII. Part 5	10	...
XXI. Part 2	99	...	XLVII. Part 6	10	...
XXI. 1 & 2 (together)	61	...	XLVII.	234	2
XXII.	164	...	XLVIII. Part 1	281	5
XXIII.	150	...	XLVIII. Part 2	322	4
XXIV.	156	...	Index to *Memoirs*	645	1
XXV.	166	...			
XXVI.	172	...			
XXVII.	422	...			
XXVIII.	382	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	66	...	XXVI.	10	...
II.	68	...	XXVII.	3	...
III.	...	...	XXVIII.	72	1
IV.	...	...	XXIX.	53	...
V.	...	...	XXX.	68	2
VI.	37	...	XXXI.	96	...
VII.	2	...	XXXII.	118	5
VIII.	139	2	XXXIII.	99	2
IX.	25	3	XXXIV.	78	2
X.	174	1	XXXV.	61	1
XI.	185	1	XXXVI.	32	1
XII.	11	2	XXXVII.	38	3
XIII.	157	3	XXXVIII.	98	2
XIV.	109	3	XXXIX.	108	1
XV.	127	2	XL.	113	3
XVI.	108	2	XLI.	113	5
XVII.	137	1	XLII.	122	1
XVIII.	167	...	XLIII.	122	1
XIX.	56	...	XLIV.	125	5
XX.	35	...	XLV.	127	4
XXI.	18	...	XLVI.	131	4
XXII.	33	...	XLVII.	130	7
XXIII.	19	...	Index to *Monthly Notices*	568	1
XXIV.	24	...			
XXV.	7	...			

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In addition to the above volumes of the *Monthly Notices*, the ociety has a considerable stock of separate numbers of nearly l the volumes. With the exception, however, of vols. XXXVI. XLVII. no complete volumes can be formed from the separate umbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided

on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

No. 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8½ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantagraph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watchcase, by Professor Chevallier.
„ 92. 2-foot protractor, with two moveable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2 feet 6 inch navy telescope with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatoreal sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Small brass astrolabe.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 116. A pair of 18-inch globes.
„ 117, „ 118. Two old sun-dials.

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 28. (2) 6-inch theodolite and stand, to Mr. Common.
„ 29. (3) Equatoreal mounting, clock movement, and stand, to Mr. W. Peck.
„ 30. (4) 3¼-inch equatoreal and stand, to Mr. E. B. Powell.
„ 31. (5) 2¾-inch telescope and stand, to Mr. Downing.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 37. (11) Zenith telescope and stand, to the Rev. H. P. Slade.
„ 62. (36) Pantagraph, to Prof. C. Pritchard.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 76. 5-prism direct vision spectroscope, to Mr. Maunder.
„ 85. Double image micrometer, to Mr. E. J. Spitta.
„ 125. 6-inch Simms telescope, to Lord McLaren.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Prof. Arthur Auwers for his re-reduction of Bradley's Observations. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

Vol. xlix. Part 1 of the *Memoirs* has just been published.

It contains Dr. Dreyer's New General Catalogue of 7840 nebulæ and clusters of stars, being the Catalogue of the late Sir John F. W. Herschel, revised, corrected, and enlarged. Believing that this Catalogue will be found of great use to astronomers, the Council have ordered an additional 225 copies to be printed.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—Joseph Baxendell.
W. R. S. Callcott.
J. B. Dancer.
Rev. Thomas Gaskin.
Rev. H. A. Goodwin.
Peter Gray.
Capt. Richard Ladd.
W. G. Lettsom.
Alfred Morris.
Balfour Stewart.
J. M. Walden.
Rev. S. W. Waud.

Associates:—Eduard Luther.
H. C. F. C. Schjellerup.

Joseph Baxendell was born April 19, 1815, at Bank Top, Manchester. He was the son of Thomas Baxendell. The groundwork of his education was laid by Mr. Whalley, of Cheetham Hill, but to a large extent he was self-educated. In his childhood he enjoyed but poor health, and when about fourteen years of age his father placed him on board the "Mary Scott," bound for Valparaiso, with the hope that the voyage would invigorate his weakly constitution. While off the coast of Central America it was his good fortune to witness the extraordinary shower of meteors which occurred on November 13, 1833; later on his ship experienced the shock of the earthquake which was attended with such disastrous results to the Pacific coast of South America. After various voyages to South America he again settled in Manchester, and with his friend Mr. Robert Worthington, of Crumpsall Old Hall, erected the Crumpsall Observatory, where the large 13-inch reflector (the speculum of which he had himself cast, ground, and polished) was mounted, beside a small 5-inch equatorial refractor; here he industriously applied the evenings of his busy days to the observation and discovery of variable stars, and the excellent work done here by Mr. Baxendell won for it a high position

amongst private observatories, and engaged him in correspondence with the most eminent astronomers, both in this country and abroad.

The private life led by Mr. Baxendell furnishes little to record; like many who have attained to scientific eminence in Manchester, he preferred to live a quiet, retired life, seeking no applause. Of his personal character it may be said that in him amiability of temper and firmness of character were happily blended. Some years since his scientific labours were interrupted by a distressing malady of the lower jaw.

In 1859 he was appointed Astronomer to the Corporation of Manchester.

In his later years he resided at Southport, where in 1871 he was appointed Superintendent of a Meteorological Observatory in Hesketh Park, fitted up and presented by John Fernley, Esq., formerly of Manchester; and in 1877 he erected his own private Astronomical Observatory in Birkdale, Southport, and resumed his observations of variable stars, &c., with a 6-inch equatorial refractor, by Cooke & Sons, assisted for some years past by his son.

In 1865 he married Mary Anne, sister to Mr. Norman Pogson, Government Astronomer of Madras; the issue of the marriage was an only son. He closed a useful life on October 7, 1887, in the 73rd year of his age.

In 1858 he joined the Manchester Literary and Philosophical Society; Mr. Baxendell was appointed Editor, and one of the Honorary Secretaries, a post which he maintained with advantage to the Society for twenty-four years; to maintain for it a position worthy of its past history seemed to be one of the objects of his life, and for this reason probably the greater and most valuable portion of his work was first made public through the medium of its *Proceedings* and *Memoirs*. In 1884 he was elected a Fellow of the Royal Society. Of foreign societies he was a corresponding member of the Roy. Phys. Econ. Soc., Königsberg, and Acad. Sc. and Lit., Palermo. In the Royal Society's Catalogue of Scientific Papers his name will be found associated with a commendable show of work. The earliest paper mentioned is one "On the Variability of λ *Tauri*," published in the *Monthly Notices*, vol. ix., 1848–49; the list also includes a joint paper by J. Baxendell and H. E. Roscoe, "On the Relative Intensities of Direct Sunlight and Diffuse Daylight at Different Altitudes of the Sun" (*Proceedings of Royal Society*, vol. xv.); besides his communications to the Society, he also contributed to the *Astronomische Nachrichten*, and towards the close of his life he published several articles in the *Observatory* and Liverpool Astronomical Society's *Journal*. But most of his work is to be found in the *Memoirs* and *Proceedings of the Manchester Literary and Philosophical Society*, to which he contributed nearly forty papers on astronomical subjects. These consist for the most part of observations of variable stars, but include also papers on

planets, comets, meteors, Sun-spots and eclipses. Any notice of Mr. Baxendell would be imperfect which gave no account of his meteorological work. Of his position as a meteorologist it has been remarked by a labourer in the same field, the late Prof. Balfour Stewart:—"Baxendell's contributions to meteorology are very important, and in one branch of the science he may claim to be the pioneer." One of his most original and important papers on this subject is entitled "On a Periodic Change in the Magnetic Condition of the Earth and the Distribution of Temperature over its Surface." In this paper he advanced a hypothesis which may be more particularly alluded to.

Considerations of the irregularities of some of the variable stars led him to regard it as highly probable that the light of the Sun, and also its magnetic and heating power, might be subject to changes of a more complicated character than have hitherto been supposed; and besides the changes indicated by the greater or less frequency of solar spots, other changes of a minor character, and occurring in shorter periods, might also take place. To account for a short variable period which he detected he supposes that there may be a ring of nebulous matter, either not of uniform density or discontinuous, circulating round the Sun in a plane nearly coincident with the plane of the ecliptic, and at a mean distance from the Sun of about one-sixth of the radius of the Earth's orbit; that the attractive force of the Sun on the ring is alternately increased and diminished by the operation of the forces which produce the solar spots, being greatest at the times of minimum frequency, and least when the spots are most numerous; the dimensions of the ring and its period of revolution round the Sun will vary, their maximum and minimum values occurring respectively at the times of maximum and minimum solar spot frequency. This ring is supposed to act not only in reflecting and absorbing a portion of the heat and light which would have otherwise reached the Earth, but also in altering the direction of the lines of magnetic force, the magnetic influence being more marked than the thermal influence. From the maximum and minimum values of the temperature period he concludes that the greatest and least period of revolution of the ring will be 29·12 and 22·08 days respectively; from these numbers he infers that the greatest distance of the ring from the Sun is 0·185, the radius of the Earth's orbit being taken as unity, the least distance 0·154, and the mean distance 0·169; the greatest attractive force of the Sun on the ring being taken as unity, the least will be 0·691. He refers to Leverrier's supposed planet within the orbit of *Mercury* acting as a disturbing body on that planet, and he states that it is remarkable that the mean distance which Leverrier seemed to regard as most probable is precisely that which he has found for the assumed ring of nebulous matter.

It is impossible in a brief notice of the scientific labours of Mr. Baxendell to refer particularly to the very numerous and

important papers he contributed to astronomy, meteorology, and sanitary science. They evince his great mental activity, and the earnestness with which he pursued his investigations. Indeed, his love of knowledge for its own sake was essentially the delight and solace of his life, and even in old age and sickness it seemed to remain as bright and unwearied as ever.

Up to the last, when discharging his editorial duties for the Manchester Philosophical Society, with which he was in a special sense identified, it was his habit not merely to read the papers which passed through his hands, but to digest them and to propound questions to the writers on the most varied subjects not in his editorial capacity, but in that of a student. This extraordinarily healthy, yet at the same time quiet, activity of a mind which never seemed to regard anything as not worth knowing, is abundantly exemplified in the record of his life. If he has not established any great generalisation or law as a lasting monument of his labours, he has at least introduced some order, directed attention to some far-reaching truths, and illuminated many obscure paths for future investigators.

He was elected a Fellow of this Society January 9, 1857.

William Robert Stuart Callcott was born on August 8, 1851, at The Mall, Kensington Gravel Pits, where his family had lived for many generations.

He was the youngest son of the late William Hutchins Callcott, the well-known musical composer, and grandson of Dr. Callcott, whose glees and other compositions have a world-wide reputation. He was also a grand-nephew of the great landscape painter and Royal Academician, Sir Augustus W. Callcott.

From his early boyhood Robert Callcott exhibited great genius, especially for music, and had all the advantages which his distinguished connection both with painting and music procured for him. He was educated at a private school at Hurstmonceux and at The Philberds, near Maidenhead, a spot to which in after years he loved to retire for rest and quiet, and where he died, after only a few days' illness, on April 7, 1886.

On leaving school he evinced a great taste for Church music. His extempore organ playing attracted the attention of the late Henry Smart, who took great interest in him and often entrusted his young *protégé* with the accompaniment of the services at old St. Pancras Church. The pupil soon became devotedly attached to the master, and the death of the latter was a great blow to him. The few years which elapsed between this event and his own death were occupied in teaching and in filling various positions as an organist, notably at Christ Church, Kensington. He possessed great aptitude for choir-training, and was especially successful in cultivating boys' voices, often out of the crudest material. At the time of his death he was engaged also in

editing and arranging, for Dr. Stainer, a new chant-book for use in St. Paul's Cathedral.

Towards the close of his short life Robert Callcott became deeply interested in Astronomy. Next to music it was his chief study, and his great delight was to deliver popular lectures on the subject. Almost his last act was to purchase the Observatory of the late Canon Chevallier, but he did not live to see it removed from the rectory at Heighington.

He was buried in the picturesque little churchyard of Bray, near Maidenhead.

He was elected a Fellow of this Society June 13, 1884.

JOHN BENJAMIN DANCER was born in London on October 8, 1812. In 1818 his father, Mr. Josiah Dancer, removed to Liverpool, where he carried on the business of an optician and philosophical instrument maker. His son very early in life evinced a strong taste for mechanical and scientific pursuits, and when the father died, in 1835, he was able to carry on the business.

After a few years Mr. Dancer removed to Manchester, where he became well known through his numerous inventions and improvements of philosophical instruments. Among these may be mentioned photographic slides for the magic lantern, which were first suggested by him; the introduction of earthenware porous jars in voltaic batteries, the preparation of microphotographs, improvements in the stereoscope, and the production of a new thermometer described by Dr. Joule as "the first made in England with any pretension to accuracy."

With regard to Mr. Dancer's connection with the microscope, it would be difficult to overestimate the stimulus he gave to microscopy in Manchester by bringing out successively several forms of instruments as excellent in their mechanical and optical arrangements as they were moderate in price.

Some few years ago his sight began to fail, and in a short time he became totally blind, and with this affliction his business declined; and it is sad to record that one who had rendered such valuable service to science should have ended his days, on November 24, 1887, in very straitened circumstances.

Mr. Dancer's active mind never lost its interest in the studies and discoveries of his earlier years. By his numerous friends his society was to the last highly appreciated, and his modest and kindly disposition greatly enhanced the pleasure and advantage of his conversation. His simple-minded devotion to every branch of physics was not less remarkable than his unfailing industry, and the inventive genius by which it was directed to results of no ordinary importance to the mechanician and the lover of natural science.

He was elected a Fellow of this Society March 9, 1855.

THOMAS GASKIN was born at Penrith, in Cumberland, on May 12, 1810. He was educated at Sedbergh School, and in

early life showed exceptional grasp of learning and assiduity of habits. As a boy he displayed a remarkable memory, and on leaving school it is said that he could repeat above twenty Greek plays by heart.

The encouraging promise thus afforded by his boyhood was afterwards realised by a career at Cambridge of exceptional brilliancy. In 1827 he entered St. John's College, where he was always placed first in the college examinations. In 1831 he took his degree as Second Wrangler, Earnshaw being the Senior Wrangler. He was also second Smith's Prizeman.

Subsequently on no less than six occasions he held the office of Moderator, which at that time was unique. Among the Senior Wranglers he examined were Leslie Ellis, Cayley, Todhunter, and Ferrers, and among his colleagues as Moderator were Stokes and Cayley. He was elected Fellow of Jesus College, and was for some years tutor of that college.

In the opinion of his contemporaries at Cambridge Mr. Gaskin was almost unrivalled for his skill in the construction and solution of difficult Senate House problems. In 1847 he published two volumes containing solutions of geometrical problems and of trigonometrical problems set in St. John's College. The problems are comparatively elementary, but his methods of solution are always interesting and excellent, and many of the processes show surprising ingenuity. They exercised an appreciable influence on the teaching of the University.

In 1852 he published a tract of 84 pages upon the geometrical construction of a conic section subject to five conditions of passing through given points and touching given straight lines. The constructions were deduced by the method of anharmonic ratio which at that time was a comparative novelty.

The appendices of his *Geometrical Problems* and his papers on conic sections, published in the *Mechanics' Magazine* for 1848, also bear testimony to his mastery of geometrical processes and skill in their development.

It is impossible to examine Mr. Gaskin's writings without failing to see that he was a mathematician of rare power, and that what he accomplished was greatly inferior to what might have been produced by one gifted with such ability if he had devoted himself to the advance of mathematical science. For example, in the problem paper set by him in the Tripos of 1839 there are several questions, including one on Probabilities and one on Riccati's equation, which might fitly have borne more ample treatment as mathematical investigations of permanent value. But he seems to have confined himself to the work of the University, and mathematical science has failed to include among her higher workers one who was probably capable of enlarging her boundaries.

With mathematical attainments of the highest order, Mr. Gaskin combined a remarkable classical knowledge, and it was considered that if he had devoted himself to classics he would have become as eminent in literature as in science.

For many years he remained at Cambridge. After vacating his Fellowship by marriage he resided for a short time at Grantchester, near Cambridge, whence he removed to Cheltenham, where the last thirty-two years of his life were spent.

For many years before his death, owing to ill health, he was unable to devote his time to work. He died 1887, March 31.

Mr. Gaskin was a Fellow of the Royal Society, having been elected 1839, March 21.

He was elected a Fellow of this Society 1836, November 11.

PETER GRAY was born in Aberdeen about the year 1807. His parents were not in affluent circumstances, but they were enabled to give their children a tolerably good education. Mr. Gray was educated at Gordon's Hospital, where he early developed signs of considerable mental power. His success there won for him the distinction of being one of the six pupils annually nominated by the Hospital to receive tuition at Marischal College. Here he devoted much of his energies to mathematics, but he also had a taste for mechanics, and while quite a young man he devoted himself to grinding lenses.

Mr. Gray appears to have begun business as a bookseller, but before leaving Aberdeen he was induced to take up the pursuit of wood engraving, which he assiduously pursued for a time, and in which he attained a certain proficiency; but all this time he had not settled down to any occupation or profession for life. His letters and papers in the *Mechanics' Magazine* on mathematical subjects, especially relating to actuarial science, made his name known; and in 1842, soon after his first contributions appeared, he came to London and accepted a position in the establishment of Messrs. Samuel Courtauld & Co.

About this time his mathematical talent developed itself, and led to his being taken in hand by the late Professor De Morgan, who showed much interest in his writings and gave him valuable assistance in many ways. While scrupulously attending to the duties of his office in the daytime, he had always leisure in the evening to devote to his mathematical researches. Actuarial science had always the chief fascination for him, and in 1849 he published an important volume of tables and formulæ for the computation of life contingencies, to which an addendum was subsequently published in 1870. The primary object of these tables is to afford the means of determining the logarithm of the sum and difference of two numbers whose logarithms are known, the numbers themselves being unknown. The problem is therefore given log. a and log. b, find log. $(a \pm b)$ by the taking out of only one logarithm. The idea and first formation of tables for this purpose are due to Gauss, but Mr. Gray was the first to perceive their utility in the calculation of life contingencies, and to him is due their introduction as well as the calculation of the necessary tables. They are throughout original calculations, and in their construction the author recalculated a

considerable portion of Matthiessen's Tables, published in 1818, and therein discovered numerous errors.

In 1865 Mr. Gray published some tables for the formation of logarithms and anti-logarithms to twelve places, with explanatory introduction; a work which has been described as "the most complete account of the simplest and best of the known methods for the calculation of isolated logarithms." A further work—*Tables for the Formation of Logarithms and Anti-logarithms to Twenty-four or any less Number of Places*—was published in 1876. The principle of the method adopted by Mr. Gray in this important contribution is the same as in his previous publication. It depends upon the resolution of the number whose logarithm is required into factors whose logarithms are tabulated; and the logarithm is obtained by summation of the logarithms of those factors taken from the table. It may be mentioned that the preface to this work contains a very full and careful history of this method with its successive developments, the final improvement, which consists in the use of three-figure factors, being due to Mr. Gray himself.

By far the greater portion of Mr. Gray's mathematical work will be found in the pages of the *Journal of the Institute of Actuaries*. His papers indicate an accurate knowledge of mathematical processes, and display a comprehensiveness and clearness of treatment which render them of standard value.

In 1874 Mr. Gray called attention to the peculiar advantages of the Arithometer of M. Thomas (de Colmar) in its application to the construction of life contingency tables, and his paper forms an extremely lucid exposition on the subject. All the applications of mathematics to numerical calculation possessed a singular attraction for him. He was an excellent calculator, and it was his delight to exemplify the refinement of modern mathematical processes by pushing calculation effected by their means to an extraordinary degree of accuracy. For example, he calculated the cube root of 2 to 56 decimal places by Horner's method, and verified its accuracy by a direct multiplication, performed by means of the Arithometer (*Messenger of Mathematics*, vol. vii. p. 51). He also calculated the values of all the surds which occur in the sines of every third degree of the quadrant to twenty-four places (*Id.* vi. p. 105). Besides his mathematical work, he devoted a considerable portion of his leisure to microscopical science, to which he was much attached.

Mr. Gray was of an exceedingly simple, genial, and affable nature. He was perhaps more a scientific man than a practical man of business. His many amiable qualities gained for him the respect and esteem of all with whom he was associated.

As years advanced his health became much enfeebled, and his old pursuits had to be given up; and he passed away on January 17 at the ripe age of eighty years. By his death the insurance profession is deprived of one of its most able members, who laboured so much and so usefully in the science of life contingencies.

Mr. Gray was for many years an Honorary Member of the Institute of Actuaries, and a Fellow of the Royal Microscopical Society.

He was elected a Fellow of this Society 1847, March 12.

RICHARD LADD was born at Wandsworth on November 5, 1848, and was educated at Dr. Semple's school at St. Margaret's, near Dover. He subsequently selected a seafaring life, and at the time of his death was navigating officer of the cable steamship *Nimia*.

Extremely fond of astronomy and meteorology, he devoted most of his leisure to their study, and with the instruments lent him by the Meteorological Society he made many useful and excellent observations. He had always looked forward to the time when he could devote all his power and energy to astronomy, but this hope was frustrated by his untimely death on May 3, 1887.

He was elected a Fellow of this Society November 9, 1883.

WILLIAM GARROW LETTSOM was born at Fulham in March, 1805. He was educated at Westminster School, and during his earlier years lived much with his grandfather, Sir William Garrow. He was originally intended for the legal profession, but his inclinations were for the diplomatic service, which he entered in 1831. He was well acquainted with Cruikshank, Thackeray, and other celebrated artistic and literary men of that time, and was a contributor to various periodicals, among others to the *Omnibus*, for which he wrote under the signature of "Dr. Bulgardo."

After serving as Attaché to the British Legations at Berlin, Munich, Washington, Turin and Madrid, he was appointed Secretary to the Legation at Mexico, where he shortly afterwards became Chargé d'Affaires. While in Mexico the British Government suspended diplomatic relations with that country for a time, owing to Mr. Lettsom's representations, and he was the object of an attempted assassination. On the satisfactory termination of the dispute he was presented with a testimonial by the English residents. In 1859 he was appointed Consul-General and Chargé d'Affaires to the Republic of Uruguay, and remained at Monte Video till 1869, when he retired from the diplomatic service.

Mr. Lettsom is perhaps best known as the joint author of Gregg and Lettsom's *Manual of the Mineralogy of Great Britain and Ireland*, which was the most complete and accurate work that had appeared relating especially to the mineralogy of the British Isles. He was much interested in spectroscopic studies, and was in correspondence with the most eminent workers in this field of research. He was the author of several papers on geological, electrical, and spectroscopic subjects; but in all branches of natural philosophy he took great interest, and his

assistance and suggestions were ever ready for the scientific inquirer.

He died of acute bronchitis on December 14, 1887.

He was elected a Fellow of this Society April 13, 1849.

ALFRED MORRIS was born at Warrington in 1837. A few years after his birth his father removed to London, where the son received his education. On arriving at manhood he visited most of the Australian colonies, as well as Tasmania and New Zealand, and finally settled at Sydney, New South Wales, where he entered the Government service as a civil engineer. He was employed upon the reservoirs for the new water supply, and in laying out some of the new railways, in the course of which work he surveyed a large portion of the New South Wales territory. He was subsequently appointed to the Public Works Department of Western Australia, and while engaged in laying out a new system of roads in this colony he overworked himself in a very hot season, and incurred an illness which terminated fatally on February 28, 1887.

He was a Fellow of the Geological Society of London, and was much thought of as a lecturer on geological and astronomical subjects, as he had the gift of imparting to others the knowledge he himself possessed.

He was elected a Fellow of the Society January 13, 1882.

BALFOUR STEWART was born on November 1, 1828. He went to school at Dundee, but entered St. Andrew's University at the age of thirteen, and thence passed on to Edinburgh, where he studied under Professor Forbes. Leaving college when he was eighteen years old he was sent by his parents to serve his apprenticeship in business with a firm at Leith, and went out to Australia with a cousin, James Balfour, to start on a commercial career. But he was never fond of business, and soon returned home to Edinburgh, where he became assistant to Professor Forbes in 1853. In 1859 he was appointed Director of Kew Observatory, and held this post until 1870, when he was appointed Professor of Physics at the Owens College, Manchester. He died of apoplexy on December 18, 1887, at Ballymagarvey, near Drogheda, whither he had gone to spend the Christmas holidays.

Balfour Stewart's name was first prominently brought before the public by his researches on radiant heat. His paper was presented to the Royal Society of Edinburgh, and read on March 10, 1858. It contains an account of experiments and arguments on the necessary relationship between the radiation and absorption of a substance. The whole science of spectrum analysis is founded on that relationship, and Stewart deserves a prominent place in the history of this branch of physics.

It is almost impossible now to realise the unsatisfactory and vague ideas which pervaded nearly all writings on the radiation

of heat during the first half of this century. Stewart was the first to show that radiation was not a pure surface phenomenon, but that it was necessary to take account of the internal radiation of bodies. He proved that if a semi-transparent body is placed in an enclosure of uniform temperature it must make up by its own radiation and reflection whatever heat it has absorbed from the enclosure. Kirchhoff shortly afterwards, and independently, treated the same subject, and it is interesting to compare the two memoirs. Stewart's reasoning is simpler, but it does not allow us to express the law in the definite and mathematical form in which it was published by Kirchhoff.

Stewart proved that the streams of radiant heat crossing any point of an enclosure are not altered by the interposition of a body, whether opaque or transparent. But the radiation crossing any point is made up of heat which has passed through different thicknesses of the transparent bodies and in various directions. What Stewart established for the sum of these streams Kirchhoff proved for each individually. The reasoning thus becomes much more complicated, but the proof more complete. Stewart showed that the law must hold for each description of heat, that is to say, for the radiation of the different wave-lengths separately: it is this generalisation which forms the foundation of the theory of spectrum analysis.

From the time of his appointment to the Directorship of the Kew Observatory until his death, Stewart's attention was principally given to the subject of cosmical physics. The connection between solar phenomena and meteorology fascinated him, and he spent much thought and labour in the investigation of this difficult and important subject. Broadly speaking, the facts are these: Certain phenomena are observed on the Sun to vary periodically. The regular magnetic oscillations, as well as the irregular magnetic disturbances, show in their behaviour a marked correspondence with the state of the solar surface. No physical theory exists to account for the connection. Unless we admit some unknown force, the Sun can only act on the Earth either by gravitation (tidal action), by radiation, or by direct electric discharges. Considering that we have no evidence whatever as to the constancy of the Sun's radiating power to within about 10 per cent., it seems only reasonable to try whether we can detect the same periodicities in meteorological and in solar phenomena.

Balfour Stewart paid attention especially to the shorter periods which have been detected or suspected in solar activity. The problem, in the absence of a well-defined physical theory, is one of very great difficulty, for it is almost impossible to decide in how far accidental regularities may mislead, and how far irregularities may hide effects, which are admittedly small. Balfour Stewart was always cautious in his statements, and tried to verify his results by repeating his reductions whenever he had an opportunity of attaining fresh material. His death is a great loss to the cause he had so much at heart, for much remains to

be done, and there are few who are willing to undergo the great labour of computation with the risk of obtaining no definite result in the end. It is impossible to give in detail an account of all Stewart's investigations bearing on sun-spots, terrestrial magnetism, and meteorology, and it will be sufficient to mention the more important results which seem well established.

Employing both Carrington's observations and those made at Kew, he, in conjunction with De la Rue and Loewy, investigated the size of sun-spots, as they passed over the solar disc, in relation to the position of the inner planets and *Jupiter*. It was found that the average size of spots attains its maximum on that side of the Sun which is turned away from *Venus* or from *Mercury*, and to have its minimum opposite these planets. This behaviour is so decided with regard to *Venus* that the whole body of observations could be split up into two parts, namely, Carrington's series and the Kew series, in each of which it is distinctly manifest.

The sun-spot period, with its average duration of about eleven years, shows very great irregularities both in the length and in the amplitude of the oscillation. Stewart has shown that from the year 1780 to 1870 the curve of solar activity can be best represented as a superposition of three oscillations, one of ten-and-a-half, one of twelve, and a minor one of about sixteen years. The irregularities would thus be produced by the beats of these three fluctuations. As regards the connection between magnetical and meteorological phenomena, perhaps the most satisfactory results were obtained in his late researches conjointly with Mr. L. Carpenter, in the connection between magnetic disturbances and the strength of the wind. A good case is made out for the conclusion that high and low disturbance values of magnetic force correspond with, and slightly precede, high and low wind values.

Balfour Stewart was the author of several text-books. His "Primer of Physics," as well as his "Elements of Physics," are well established as sound and clear elementary books. His book on heat is an excellent treatise, and his "Lessons in Elementary Practical Physics," written jointly with Mr. W. W. Haldane Gee, is the most complete exposition of experimental methods in Physics which has been written. He contributed to the International Scientific Series an admirable treatise on the Conservation of Energy. Stewart was also the author of the article "Terrestrial Magnetism" in the last edition of the *Encyclopædia Britannica*. The Royal Society Catalogue of Scientific Papers gives a list of 75 papers of which Prof. Balfour Stewart was either the sole or joint author. He was elected a Fellow of the Royal Society in the year 1862, and obtained the Rumford Medal in 1868. At the time of his death he was President of the Physical Society, and of the Manchester Literary and Philosophical Society.

He was elected a Fellow of this Society April 12, 1867.

A. S.

JOHN MAY WALDEN was born in the island of Guernsey in the year 1839. He served his apprenticeship to Mr. Courtney, watchmaker, of that island, and afterwards removed to London, where he resided for twelve years. He subsequently settled at Jersey, where in connection with his business he gave particular attention to the regulating of chronometers. As at this time there was no telegraphic communication between England and Jersey, there was no direct means of obtaining Greenwich time. Mr. Walden built a small observatory, and mounted a transit instrument, with which he was able to make the necessary time observations. He was devoted to his profession, and while earning for himself the reputation of being a skilful workman he had added to it that of a most scrupulously honest and straightforward business man. He died on January 16, 1887, from a severe attack of congestion of the lungs.

He was elected a Fellow of the Society February 11, 1876.

SAMUEL WILKES WAUD was born on August 26, 1801. He was educated at Magdalene College, Cambridge. He graduated in 1825, taking high mathematical honours as Fifth Wrangler, and subsequently became fellow and tutor of his college. Mr. Waud took holy orders, being ordained deacon in 1827 and priest in 1828, and was eventually presented by the Bishop of Ely to the living of Rettenden, in Essex, which he held to the time of his death. Gifted with a large and generous nature, he was deeply beloved and respected in his parish, the whole of the duties of which he performed unaided, even when he had passed his eightieth year. In the earlier part of his life Mr. Waud delivered some lectures on astronomy at Cambridge, and he published in 1835 a treatise on algebraical geometry. He retained his mental powers to the very last, always finding a pleasure in reading the classical authors and in teaching his children. He died February 24, 1887.

He was elected a Fellow of the Society November 13, 1834.

EDUARD LUTHER was born on February 24, 1816, at Hamburg, where he received his early education. In his youth he showed considerable mathematical ability, far beyond his years. After passing his examination he, in the year 1837, entered the University of Kiel, and devoted himself entirely to mathematical study.

In the year 1841 he went to the Königsberg University to prosecute his studies in astronomy, mathematics, and physics, under the distinguished Professors Bessel, Jacobi, and Neumann. Here the fine influence, chiefly of Jacobi and Bessel, favoured the development of his great talents, and determined his selection of an academical career.

In 1846 he took his degree as Doctor of Philosophy, his dissertation being on the algebraical solution of equations of the fifth degree, subsequently published in vol. xxxiv. of *Crelle's*

Journal. Having thus become a member of the University, he, in the following year, as "Privat Docent," delivered some courses of lectures.

In the year 1854 Luther was appointed Professor "extraordinarius" of the University of Königsberg, and in 1859, on the appointment of Dr. C. A. F. Peters to Altona, he succeeded him as Professor "ordinarius." He was Pro-rector from 1868 to 1869, and at various times he occupied all the distinguished posts of honour in that University.

On the death of Dr. Busch, in 1856, Luther undertook, in common with the observer Wichmann, the Directorship of the Königsberg Observatory, in which post he continued until the death of the latter in 1859. Conjointly with Wichmann, he edited volumes 28, 30, and 31 of the *Königsberg Observations*, but the subsequent six volumes were published solely by himself.

Encouraged by his friend Jacobi, Luther in the year 1850 undertook the task of computing the perturbations on one another of all the major planets, including *Neptune* (then recently discovered), and also considering the minor planet *Vesta*. These computations were made after a new method invented by his distinguished master, respecting which Luther published in 1852 a note in the *Bericht* of the Berlin Academy, entitled, "*Bericht über die nach Jacobi's Methode ausgeführten Störungsrechnungen.*" After Jacobi's death the results were published in the *Monatsberichte* of the Berlin Academy. About the same time Luther was invited by Professor Dirichlet to undertake the publication of the literary remains relating to geodesy of this great mathematician. These posthumous papers of Jacobi were subsequently published, with Luther's comments and supplementary notes, in the *Astronomische Nachrichten.*

Luther had always proposed to himself, as one prominent task of his life, to complete some work of his great and highly honoured teacher Bessel. Having completed the above important work on the perturbations of the planets, he in the year 1859 published, as an inaugural dissertation, a paper entitled *Declinationes stellarum fundamentalium novæ ex ultimis illustrissimi Bessel Observationibus derivatæ.* This treatise on the declinations of the thirty-six Bessel standard stars is based upon the latest observations made by Bessel with the Repsold meridian circle, and it includes a new determination of the geographical latitude of the Königsberg Observatory resulting therefrom. From the exactness of the observations employed and the refinement of Luther's computations the latitude of this observatory is justly considered as one of the best determined in the world.

The last work published by Luther was a careful investigation of Bessel's zone observations between $-15°$ and $+45°$ declination. The zones, as printed in the volumes of the *Königsberg Observations*, are carefully compared with the original documents, and an index is added to all errors, variations, and

original remarks, so that any future reference to the original manuscript observations is now unnecessary.

Besides the works already referred to, Luther published many papers relating to the observations made at the Königsberg Observatory and the results derived from them.

Luther's lectures on astronomy were based mainly on those of Bessel which have never been published, but which were thus made known to his disciples.

As a teacher Dr. Luther was most diligent and conscientious, and there are many who remember with gratitude the instruction he gave them so readily and clearly, and with so many sacrifices of his time and strength. His nature was both amiable and philanthropic, and he was greatly respected. After protracted sufferings he passed tranquilly away on October 17, 1887; and with him has departed one of the last of the school of the illustrious Bessel.

Dr. Eduard Luther was elected a Foreign Associate November 11, 1864.

Hans Carl Frederik Christian Schjellerup was born on February 8, 1827, at Odense, a provincial town in Denmark, where his father was a jeweller. He was at an early age apprenticed to a watchmaker, but by private study he succeeded in supplementing the education he had received in his native town so well that he was able to pass the entrance examination at the Polytechnic School of Copenhagen in the autumn of 1848. Here he distinguished himself by his mathematical ability, and was able to finish his studies in the short space of two years, when he passed the final examination in applied mathematics and mechanics.

In 1851 he was appointed observer in the old University Observatory at Copenhagen, which had been built at the time of Longomontanus on the top of a high tower within the city, and was therefore, after the lapse of two centuries, greatly behind the times in every way. It had repeatedly been improved and furnished with new instruments, but there was only room for small ones, and they could not be firmly mounted, owing to the unsuitable locality. Shortly afterwards Schjellerup was also appointed instructor in drawing at the Polytechnic School, and in 1854 Professor of Mathematics at the Naval Academy.

The Professorship of Astronomy in the University became vacant in 1855 on the death of Professor Olufsen, but not being a graduate of the University Schjellerup was debarred from obtaining it, and as the erection of a new Observatory was in contemplation it was considered desirable to appoint a man with an already acquired name, for which reasons d'Arrest (then assistant at the Leipzig Observatory) was selected. Schjellerup retained the above-mentioned appointments till the time of his death; and though he was in 1875, after the death of d'Arrest,

strongly urged by the Minister of Public Instruction to allow himself to be appointed Professor of Astronomy, he preferred remaining as he was, partly owing to the pecuniary loss the change would have entailed, partly because his position at the Observatory demanded but little routine work, while his other duties left him sufficient leisure to pursue his studies in whatever direction he chose.

As long as Schjellerup had only at his disposal the instruments of the old Observatory, he chiefly occupied himself with the computation of orbits of planets and comets, among which his determination of the orbit of the comet of 1580 deserves to be specially mentioned. This was founded on a complete reduction of Tycho Brahe's original observations of the distance of the comet from stars and of his time determinations by altitudes and azimuths of standard stars.

In 1861 the new Observatory was finished, and furnished with an 11-inch refractor by Merz and a transit circle by Pistor and Martins. With the latter Schjellerup commenced in September 1861 to observe zones of stars, chiefly of the eighth and ninth magnitude, between $+15°$ and $-15°$ declination, and already in the beginning of December 1863 he had finished a series of ten thousand observations, while the reductions had been pushed on with so much energy that the complete catalogue of mean places for 1865 was laid before the Royal Danish Academy of Sciences a month after. When it is remembered that the author of this work had no assistance whatever in making the observations, and in their reduction, and that he during the greater part of the year had to spend three or four hours a day in teaching, it will be conceded that he made good use of his time. The Star Catalogue is so well known for its fulness and accuracy that it is unnecessary to dwell further on it in this place. After its completion Schjellerup intended, and had already commenced, to continue the observations north of the limit of $+15°$, as Bessel had done forty years before, but about this time his interests took a new direction, which made him discontinue systematic observations, while he was probably also influenced by the circumstance that the great undertaking of the *Astronomische Gesellschaft*, viz. the observing of all stars in the Northern Hemisphere down to the ninth magnitude, was just then planned, whereby zone work on Lalande's plan became of less importance north of the equator.

In 1866 Schjellerup published in the *Astronomische Nachrichten* his well-known catalogue of red stars, compiled from all existing star catalogues and observatory annals. It appeared most opportunely at a time when researches on the constitution of the stars were being made by means of the spectroscope, and it gave a great impulse to the study of the red stars. (A second edition appeared in 1874 in the *Vierteljahrsschrift*.) Compilations of this kind Schjellerup frequently made for his own use, but no others have been published except an index to

the observations of fixed stars in vols. 1–66 of the *Astr. Nachr.* (*Publication d. Astr. Gesell.*, viii.).

About the time of the completion of the star catalogue, Schjellerup, with his usual energy, threw himself into the study of oriental languages, especially Arabic and Chinese. In the Royal Library of Copenhagen he found a manuscript of the description of the heavens by the Persian astronomer Abd-al-Rahman al-Sûfi, a work which up to that time had been very little known among astronomers. Finding that it contained a complete and carefully made uranometry of the tenth century, or, in other words, of an epoch nearly equidistant between Ptolemy and Argelander, and at which no other estimations of stellar magnitudes are known, he resolved to translate it, and was fortunate enough to obtain the use of another MS. from the Imperial Library of St. Petersburg. After a long delay the work was published in 1874 by the Academy of St. Petersburg under the title "Déscription des Etoiles Fixes, composée au milieu du dixième siècle de notre ère par l'Astronome Persan Abd-al-Rahman al-Sûfi." It has been found most valuable by the astronomers, who of late years have studied the relative brilliancy of the fixed stars, and Al-Sûfi's results (which in the introduction to the work are put together in a synoptic table next Ptolemy's and Argelander's), have been systematically collated with their own by Messrs. Peirce, Pritchard, and Pickering.

The great value which this old work was found to possess for modern research induced Schjellerup to endeavour to make other observations of the ancient astronomers fruitful for the investigations of the present day. He had at first intended in a separate work to discuss these observations, chiefly with a view to their being used for the improvement of the lunar theory; but the difficulty he had found in getting the translation of Al-Sûfi published made him give up this idea, and in 1881 he began to publish a series of papers entitled "Recherches sur l'Astronomie des Anciens," of which, however, only three have yet been issued in the journal *Copernicus*. The first deals with the method adopted at Alexandria for determining the time during the night, and it shows that the time stars of Hipparchus had been so well selected that their culminations gave the correct time every hour within a minute. The second paper discusses the Chinese observations of the total eclipses of the years -708, -600, and -548, and shows that the theoretical value of the secular acceleration cannot make the zone of totality for these eclipses pass through the principality of Lu (where the observations must be supposed to have been made), thus seeming to point to the necessity of assuming a retardation of the sidereal day$=9^{s}\cdot55\,t^{2}$, where t is the number of centuries from 1800. The third paper compares seven conjunctions of the Moon with fixed stars, recorded by Ptolemy, with Hansen's lunar tables. The series was further to include papers on the occultations of planets observed by the

Greek astronomers on the conjunction of *Mars* and *Jupiter* 498, May 1 (observed by Thius), and the principal eclipses of the Middle Ages, but his investigations on these subjects are still unpublished. We have, however, reason to believe that as much as is ready for publication will yet be printed as soon as circumstances permit. It may here be remarked that Schjellerup often went through long calculations merely to answer some question which had occurred to him during his reading, while he rarely published anything of this kind, feeling no anxiety to bring his name before the public unless he had something of special and permanent interest to communicate.

In addition to being a man of very extensive knowledge, both scientific and general, Schjellerup was a kind teacher and friend, always willing to assist with his vast store of knowledge anybody who consulted him. He died at the Copenhagen Observatory on November 13, 1887, after a prolonged illness, leaving a memory which will be gratefully cherished by those who had the good fortune to know him.

He was elected an Associate of this Society January 10, 1879.

J. L. E. D.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

The regular meridian observations of the Sun, Moon, major planets, and minor planets down to the $10\frac{1}{2}$ magnitude have been continued as before, during the year 1887. As regards stellar work, the observations for a Ten Year Catalogue, epoch 1880, were completed in 1886; and for the year 1887 a new working catalogue of about 5,000 stars has been prepared, to contain:

(1) All standard stars, such as are generally included in Greenwich Catalogues, moon-culminating stars from 1887 onwards, close circumpolars, stars near the horizon and zenith, and stars to the 4th magnitude inclusive.
(2) Stars from Groombridge's Catalogue, and from the Harvard Photometry not in the Nine-year (1872) or Ten-year (1880) Catalogues.
(3) Additional stars from Piazzi's Catalogue, which are being added as occasion offers.
(4) Miscellaneous stars for special purposes, comet and small planet comparison stars, &c.

Of these 1,800 have been observed during the year, the total number of transits recorded being 5,916, and of meridian zenith distances 5,628.

The mean error in R.A. of Hansen's Lunar Tables with Prof. Newcomb's corrections, as deduced from 106 observations with the transit circle in 1887, is $+ 0^s{\cdot}068$; the corresponding quantities for 1883, 1884, 1885 and 1886 being respectively $+ 0^s{\cdot}032$, $+ 0^s{\cdot}021$, $+ 0^s{\cdot}028$ and $+ 0^s{\cdot}029$. The five years are consistent in showing an annual period of $0^s{\cdot}25$ amplitude, with a maximum in September and a long minimum distributed from January to April inclusive. The mean increase in 1887 as compared with the other years is fairly distributed throughout the year.

Five determinations of flexure of the transit circle in 1887

gave results $-0''.15$, $-0''.17$, $-0''.13$, $+0''.12$, and $+0''.02$. The mean from observations in 1886 was $+0''.14$.

The apparent correction to the nadir observation deduced from reflection observations of stars is insensible in 1887, the mean for the year being $+0''.006$. No correction for this discordance has been applied during the year. A new catalogue has been prepared of stars to be observed by reflection, selected with a view to proper distribution in zenith distance, from those observed since 1882, when the new mounting of the collimators rendered it possible to extend such observations to considerable zenith distances. The corrections for R—D as found in the separate years since that time have been remarkably accordant, and the mean has been adopted for use in the Ten-year Catalogue.

A recent investigation shows that the probable error of a single determination of zenith point by the reflection and direct observation of a star is $\pm 0''.43$, and thus on a fine night the probable error of adopted zenith point is about $\pm 0''.20$.

The errors of the new micrometer screws for the microscopes of the transit circle have been carefully investigated, and have been found too small for the advantageous application of corrections. A good deal of attention has been paid to the readings of exterior and interior thermometers in various positions as affecting zenith distance observations, especially those made in the daytime. Further experiments are to be made on this point in 1888 with thermometers suspended at the north and south angles and at the middle of the shutter-opening.

The personal equation machine is now in satisfactory working order, and one series of observations (for the determination of change of personality with varying rate of stellar motion) has been completed, and the results published in the *Monthly Notices*. The machine has been dismounted during the winter, but in the spring an investigation of personality in observing limbs will be undertaken.

Satisfactory progress has been made with the reductions for the Ten-year Catalogue (1877–1886). The first twelve hours of right ascension, containing 1,896 stars, are complete with the exception of the final examination of discordances, and it is hoped to have the whole twenty-four hours reduced very shortly.

Extra-meridional observations of the Moon with the altazimuth have been made as before at every opportunity in the first and last quarters, and occasionally at other times. The instrument has also been used for observations of personality depending upon the direction of motion in the case both of stars and limbs. The results for stars agree well with those already obtained with the personal equation machine, and those for limbs will be available for comparison with future series.

Comet *e* 1886 (Finlay) has been observed on two nights; Comet *b* 1887 (Brooks) on eight nights: Comets *c* 1887

(Barnard), *d* 1887 (Barnard), and *f* 1887 (Olbers) on one night each, and Comet *e* 1887 (Barnard) on three nights. The single observation of Comet Olbers is the outcome of a number of nights' watching, the weather having been uniformly bad in the early morning hours. Twenty-one disappearances and eleven reappearances of stars occulted by the Moon have been observed: in eight cases by two, and in two cases by three observers. These numbers are considerably above the average.

Careful arrangements were made for observing the occultations of stars during the total eclipse of the Moon on January 28, 1888. The observing list sent by Prof. Struve was checked and found to be accurate. Nine telescopes were assigned to different observers, of which four, however, were refractors of only 4-in. aperture. The weather was unfavourable, cloud covering the Moon almost continuously throughout totality, so that the smaller instruments were useless. In glimpses of clear sky the disappearances of six stars and the reappearances of eight were observed with the larger instruments, three of these by three observers and three by two observers. In three cases the disappearance and reappearance of the same star were observed.

Three small devices, suited to the particular circumstances of what promises to be an important class of observations, were found specially useful, and may be worthy of record. In the case of two instruments the eyepiece was mounted excentrically from the axis, at the distance of the Moon's radius, so that, without disturbing the position of the telescope, any point of the limb could be brought into the centre of the field. For setting the position-circles rapidly in the dark, cardboard circles, with notches cut at important points which could be felt and counted with the fingers, were used; and in another case luminous paint was found to work admirably for indicating the figures.

Twenty phenomena of *Jupiter's* satellites have also been observed. Owing to the unfavourable position of the planet, this number is smaller than usual.

A large amount of experimental work has been done during the past year in connection with stellar photography. Arrangements were completed in February for taking photographs with the Lassell reflector; and besides small preliminary plates, several circular plates of $8\frac{1}{4}$ inches diameter were exposed. The results seemed to show that—

1. The mounting allowed of too much shake in the telescope, resulting both from slight wind and from the small motions required at times to correct defective clock-driving.

2. The reflective power of the mirror surface is now somewhat low, so that very long exposures are necessary.

On the return of the Astronomer Royal from the International Photographic Conference at Paris, where he had undertaken to make experiments as to the possibility of using curved plates, one of the 4-in. photoheliograph object-glasses, by Dall-

meyer, used in the Transit of *Venus* (1874) Expedition, was mounted on the Sheepshanks' Equatorial with a view to carrying out these experiments. Preliminary photographs on flat plates for the determination of focus gave unexpectedly good results, especially as regards extent of field, the star images being sensibly circular to nearly 2° from the centre of the field. Accordingly some mechanical improvements having been made in the instrument, two long series of photographs of the *Pleiades* with different exposures, and in different parts of flat and curved plates respectively, have been obtained. The total number of plates taken is as follows:—

8 plates 5 in. × 4 in.; flat.
17 „ 6 in. × 6 in.; „
13 „ 6 in. × 6 in.; curved.

the total number of exposures being 128, varying from a fraction of a second to an hour. Comparison of the results indicates that the advantages of using curved plates are doubtful, while micrometric measures made on the flat plates show that for some distance beyond the limit where the star images are sensibly circular, their relative places can still be measured with the accuracy of meridian observations, and with no sensible systematic error depending upon magnitude or time of exposure.

As an experiment on the adaptation of an ordinary refractor to photography, a corrector consisting of a concave crown and convex flint lens was constructed to be placed about 30 inches within the focus of the South-East Equatorial, the effect being to bring the rays F and H to the same focus without alteration of the focal length for the former ray. The field available with this combination is very small, but some satisfactory photographs of *Jupiter* and *Saturn* and of close double stars were obtained, a Dallmeyer doublet ("rapid rectilinear") being used in most cases to enlarge the image about eight times before it was received on the photographic plate.

The regular observations with the spectroscope for the determination of the motions of stars in the line of sight have been intermitted twice during the past year, viz. from February 16 to the end of June, when the South-East Equatorial was in use for photography, and from the middle of November to the end of the year, when attention was paid to the spectra of γ *Cassiopeiæ*, β *Lyræ*, and several stars of *Secchi's* third type in compliance with a request from Mr. Lockyer. The results for motion in the line of sight are thus not so numerous as usual; in all 368 measures of displacement of either the F or *b* lines have been obtained from the spectra of 44 stars, besides 6 measures of the displacement of the F line in the spectrum of the great nebula in *Orion*, and 45 measures of lines in the spectrum of the Moon or sky, as a check on the adjustment of the instrument and general accuracy of the measures. The observations of stars

with bright lines or fluted spectrum are still in progress, γ *Cassiopeiæ*, β *Lyræ*, *Mira Ceti*, β *Pegasi*, and α *Orionis* having been examined.

With the photoheliograph, photographs of the Sun have been taken on 213 days, and 432 selected for preservation. The additional photographs obtained from India and Mauritius leave only six days in the year ending 1887, October 31 on which no photograph is as yet available for measurement. The decrease in spotted area has continued throughout 1887, though there was a partial recovery at the beginning of the year from the marked period of quiescence in the autumn of 1886.

The chronometer work has been very heavy during 1887. In addition to the ordinary issues for repair and testing on return from service, a series of competitive trials of chronometers and deck watches has lasted continuously throughout the year, with the exception only of two periods of a fortnight each.

Arrangements for enlarging the computing-rooms, and adding a third story with 18 feet dome, were completed in the autumn, and operations were commenced in November. It is proposed to transfer the photoheliograph, which has hitherto been placed in a temporary wooden hut, to the new dome; and if, as is hoped, a new photographic equatorial is eventually obtained, that instrument will be mounted there, the photoheliograph tube being carried on the same mounting.

An equatorial, by T. Cooke & Sons, has been mounted in the south ground for observation of occasional phenomena.

The volume of *Greenwich Observations* for 1885 was distributed last October, and the printing of that for 1886 is well advanced. The reduction of the observations of all kinds is in a forward state.

It may be mentioned that the Astronomer Royal attended the Conference at Paris on Stellar Photography. Mr. Turner, aided by a grant from the Royal Society, went to Russia to observe the Total Solar Eclipse of 1887, August 19.

Royal Observatory, Edinburgh.

During the above year star observations for time have been continued as usual. The daily time-signals by electric time-ball on Nelson Monument, electric time-gun at the Castle, and electric control of many public clocks, partly direct and partly at second-hand—through the trusty medium of Messrs. Ritchie & Sons, clock-makers in Edinburgh and Leith—have also been given as usual.

The bi-diurnal observations at fifty-five stations of the Scottish Meteorological Society have been computed at the Observatory for the purposes of the Registrar-General of Births, Deaths,

&c., and have been printed immediately and successively in that officer's monthly and quarterly returns.

The MSS. with plates (to the number of 221) of a new volume—chiefly spectroscopic—of the *Edinburgh Observatory Series*, to be vol. xvi., has been finished after a year's concluding work upon it. Application has therefore been made to Her Majesty's Government for leave to print it, and official correspondence on the subject is progressing.

The astronomer has also contributed a rather exhaustive paper on the finishing of the great reflecting equatorial of the Observatory to the Council of the Royal Society, Edinburgh; and they in their turn have had it read before a full meeting of the Society.

While waiting for the result of both that proceeding and the printing correspondence for vol. xvi., the Astronomer has been preparing a series of thirty-one chronological tables of Scottish mean meteorology, extending month by month from the year 1856 to 1887 inclusive; and is even beginning a still longer series to show the local excesses of individual stations in each month in single years throughout the mainland and islands of Scotland, by utilising the something like seventy millions of figures which have already passed through the Observatory in carrying out the Government's meteorological returns.

Yet the working power of the Observatory has in reality been kept up with the greatest difficulty through the year, by reason of the continued absence during almost the whole of that time, on repeated medical certificates of one of the only two assistants belonging to the Observatory, viz., the second assistant astronomer. The straits of the occasion, however, partly alleviated by the voluntary services of an excellent mathematical student of suitable temperament, who appeared at the right time, have served to exhibit, in still stronger light than before, the masterly aptitude of the first assistant astronomer, Mr. Thomas Heath, B.A., of T.C.D., in disposing of vast quantities of figure-work with method, precision, and dispatch; and he has the astronomer's warmest private thanks as well as public acknowledgments therefor.

Royal Observatory, Cape of Good Hope.

Observations with the transit-circle have been continued regularly throughout the year, the objects of observation being the Sun, *Mercury* and *Venus*, the stars on the list of the Cape Ten Year Catalogue for 1890, comet comparison stars, stars occulted by the Moon, stars employed in the latitude and longitude determinations of the Geodetic Survey, and stars employed in zones for determining the scale-value of the heliometer. The work accomplished has been as follows:—

Number of determinations of collimation	53
„ „ level	417
„ „ nadir	415
„ „ runs	413
„ „ flexure	53
Number of observations of the meridian mark	562

	Direct.	Reflex.
Number of observations of stars in R.A.	5584	274
„ „ „ N.P.D.	5098	270
Observations of both limbs of the Sun in both elements	178	
Observations of Mercury	112	
„ Venus	145	

During the winter period, April 1 to September 30, a large number of double transits of circumpolar stars have been secured, which complete the data for the formation of a new fundamental catalogue of southern circumpolars, which will soon be ready for press.

On account of the illness of Mr. Pett, who was charged with the employment of the Great Indian theodolite (an illness which necessitated his absence in England during the last six months of the year), the work with that instrument was much interrupted. The amount of work done has therefore been limited, viz. :—

61 Observations of azimuth of fundamental circumpolars at greatest elongation.

47 Observations of azimuth of other stars at greatest elongation.

77 Azimuths of pairs of N. stars for latitude (Kapteyn's method).

55 Observations of the azimuth marks.

13 Determinations of runs.

With the zenith telescope 365 pairs of stars have been observed in connection with the latitude (Kapteyn's method), and for control on the law of flexure of the transit-circle.

The general rule has been adhered to of observing all comets visible south of the Equator, or which otherwise cannot be favourably observed in the northern hemisphere.

a 1887 was observed on 6 nights between Jan. 22 and Jan. 28.
f 1886 „ 4 „ „ April 29 „ June 16.
e 1887 „ 12 „ „ May 19 „ June 17.

f 1886 was picked up by Mr. Finlay whilst sweeping for comets on April 29 in the early morning, and his observations are probably the only existing ones of that object after perihelion.

The following occultations of stars by the Moon have been observed:—

Disappearance at the bright limb	1
Reappearance at the bright limb	1
Disappearances at the dark limb	20
Reappearances at the dark limb	19
Total	41

The photographic *Durchmusterung* has been pushed forward as rapidly as possible. Recently a supply of Derby dry plates has been received, and these permit the exposure to be reduced to half-an-hour instead of one hour, as formerly. The work will henceforth proceed much more rapidly. During the year 387 perfectly successful plates have been taken in connection with the *Durchmusterung* besides 82 rejected plates, and 43 plates for the selection of comparison stars for heliometer observation and for various miscellaneous and experimental purposes.

All the plates from declination $-90°$ to $-57°$ have been transmitted to Professor J. C. Kapteyn; the zones to declination $-46°$ are all but completed, and great progress has been made as far as declination $-34°$.

Professor Kapteyn has completed the measurement reduction and cataloguing of the stars from declination $-90°$ to $-78°$. The following are the comparative number of stars in the zones of the southern *Durchmusterung*, compared with Argelander:—

	No. of Stars in Northern Durchmusterung.	No. of Stars in Southern Durchmusterung.
$-80°$	793	921
$-81°$	844	920
$-82°$	751	822
$-83°$	675	739
$-84°$	547	648
$-85°$	412	543
$-86°$	347	396
$-87°$	220	363
$-88°$	143	252
$-89°$	38	66
Totals	4770	5670

Professor Kapteyn has secured additional pecuniary aid, partly from his Government and partly from scientific societies in Holland, and he is now making such rapid progress in the measurements and their reduction that he expects to complete the whole work within four years. The photographic work at the Cape will probably be completed within the next two years.

During the first six months of the year H.M. Astronomer was absent from the observatory for the purposes of inspecting the new heliometer (completed for the observatory by Messrs. Repsold in Hamburg), of attending the Astrophotographic Congress in Paris, and passing some observatory publications through the press.

The heliometer reached the observatory by the steamer in which Mr. Gill returned, and was erected and adjusted without accident or delay.

The instrument is now in perfect order and adjustment, and regular work has been commenced.

It is in every respect perfect, and is, without doubt, the most powerful and convenient instrument for refined micrometric research at present in existence.

A complete working programme has been prepared, including the determination of the parallax of all the southern stars brighter than magnitude 2·0, and all the stars most remarkable for proper motion.

The necessary comparison stars (in general two pairs at least for each star) have been selected; the epochs of parallax maxima and minima and other necessary preliminary computations have also been completed. Some progress has been made in the determination of the errors of division of the scale and screw, as well as in the scale-value and other constants of the instrument, and work on the parallax determination of a few of the stars has been commenced.

Some inconvenience was at first encountered by the inefficiency of ordinary batteries to charge the accumulators necessary for the supply of electric light; but this difficulty has been overcome—first, by use of a dynamo kindly lent by a firm in Cape Town, and since by the liberality of the Lords Commissioners of the Admiralty in sanctioning a proper dynamo and set of accumulators for the electric illumination of all the instruments of the observatory. The wires have been laid down, and Mr. W. H. Preece, F.R.S., has kindly superintended the construction of the new dynamo and accumulators, which will reach the Cape before the end of January.

The field work of the Geodetic Survey, mentioned in last year's report, has been completed by the execution of the triangulation from King William's Town to Port Elizabeth, by the telegraphic redetermination of the astronomical longitude of Port Elizabeth, and by final latitude and azimuth observations at the same station. Major Morris, R.E., is about to take up his quarters at the observatory, and the work of final reduction will be immediately undertaken.

The measured length of the base line at Port Elizabeth (mentioned in last report) differs from its length computed through about 500 miles of triangulation from the Natal base by two inches.

The minute corrections (hardly reaching 0″·1 in any case) applicable to the measured angles will be computed so as to equalise the computed and measured lengths of these bases.

The probable errors of the measured bases are in each case less than 0·05 inch.

The Cape Standard Ten-foot Bar A has been compared at the International Bureau of Weights and Measures at Paris, and an apparatus has been devised by H.M. Astronomer, and constructed by Messrs. Troughton & Simms, for determining the absolute constants of the measuring bars by comparison with the Standard Bar A.

Absence from the observatory, the erection and adjustment of the heliometer, together with the heavy pressure of a great variety of work requiring the close personal attention of H.M. Astronomer, have rendered it impossible for him to complete the reductions of the observations of *Victoria* and *Sappho* made in 1882, but it is expected that the work will be completed within the current year.

The following works were passed through the press by H.M. Astronomer during his visit to England:—

"Meridian Observations made at the Royal Observatory, Cape of Good Hope, during the years 1882, 1883, and 1884."

"Occultations of Stars by the Moon observed at the Royal Observatory, Cape of Good Hope, in the years 1835 to 1880, compared with Hansen's Tables of the Moon." Annals of the Cape Observatory, vol. i. part 4.

"On the Variations of the Instrumental Adjustments of the Cape Transit Circle," by W. H. Finlay, M.A., Chief Assistant. Annals of the Cape Observatory, vol. ii. part 2.

The meteorological observations made in the year 1886 at the observatory, together with those taken in different parts of the colony, have been printed in the "Report of the Cape Meteorological Commission."

Armagh Observatory.

The micrometric observations of nebulæ mentioned in previous reports have not made much progress during the past year, but the refractor was employed to examine a number of doubtful cases which presented themselves during the compilation of a new general catalogue of Nebulæ. To the preparation and passing through the press of this work (which has just been published in the *Society's Memoirs*) the Astronomer has had to devote almost his whole time.

Cambridge Observatory.

In carrying out the plan of observing each of the stars in our zone, if possible, at least three times, 2,047 observations have been made with the meridian-circle for the determination of Right Ascension and North Polar Distance. Of these 719 were observations of standard stars for clock correction; and 74 observations of *Polaris* above pole, involving 178 circle readings, and 66 below pole, involving 140 circle readings, were made for instrumental correction; 67 were observations of stars compared with *Sappho*; and the remaining 1,121 were observations of zone stars. Some of the zone stars in the observing list are so faint that they can only be taken on very clear nights, and few such have occurred during the year. Clock stars have been observed on 149 nights, of which only 93 were found to be suitable for the observation of zone stars, and few out of the 93 were clear enough for the very faint ones.

The Zenith Point, the Level Error, and the Error of Collimation have each been determined 227 times.

As regards the reductions and formation of the catalogue:—The true North Polar Distance of all the stars is calculated up to October 15, 1887, and the true Right Ascension to the end of July 1887. For the standard stars, the mean co-ordinates for the beginning of the year are obtained up to the end of 1886; for the zone stars to the end of 1883. The zone stars are reduced to the epoch in North Polar Distance up to August 1880, and in Right Ascension up to March 1880.

For the formation of the catalogue of zone stars, the Mean places for the epoch, 1875, are collected to the end of 1878, from 0^h to 5^h Right Ascension.

As in previous years, we have been called on several times for places of stars with which other heavenly bodies had been compared.

On June 30 places of four zone stars were furnished to Dr. Holetschek of Vienna. One had been observed by us four times, one three times, one twice, and one once. Another which he required, being smaller than the 9th magnitude, and having no letter annexed to it in Argelander, did not come within the scope of our zone work, but it will be observed when the proper time of year comes round.

On July 13 Mr. Bryant was furnished with places of seventeen stars which had been compared with the planet *Sappho*, deduced from sixty-four observations with the transit-circle; and also with seven places of *Sappho*, obtained from comparisons with ten of these stars in January and February 1887, by means of the Northumberland equatorial and square bar micrometer.

Mons. C. F. Pechüle, of the Copenhagen Observatory, asked for the places of forty-three stars. Thirty-six of these, deduced

from ninety-eight observations, were forwarded to him on September 21; the others, which do not strictly lie within the limits of our zone, will be observed in due course.

Dunsink Observatory.

Since the date of last year's report the observation of stars known or suspected to have a large proper motion has been continued. During the year a number of stars has been added to the working list, which at first did not contain a great many, having been compiled almost exclusively from the sources mentioned in our report for 1886. Early in the year, however, all the stars given by Dr. Dreyer in the *Monthly Notices* for May 1886 were included, as well as all the stars in the *B.A.C.*, which are there credited with a proper motion greater than $0''\cdot2$ annually. Although many of these proper motions rest on the slenderest foundation, it was thought better to include them in the list for the sake of uniformity, as having been at one time suspected of a motion greater than that amount which was the limit decided upon when commencing the list. These, with a few stars which have been from time to time found in the *Astronomische Nachrichten*, have raised the number on the working list to nearly a thousand.

The meridian-circle and chronograph have, throughout the greater part of the year, been devoted to observations of these stars. There have been 1,028 meridian observations, of which 524 were observations of R.A. and 504 of Declination. The collimation error has been determined 150 times, the level error 83 times, the nadir point 173 times, and the error of run of the microscope 47 times. There have been 193 observations of the R.A. of standard stars for the determination of clock and azimuth errors, and 65 of Declination to serve as a check on the reading of the nadir point.

In November a series of observations was commenced of the zenith distance of *Polaris*, direct and reflected, at both culminations and in both positions of the instrument for the determination of the latitude. By the end of the year 92 such observations had been taken. A number of measures were also made of two spaces, one on each circle, which are employed for determining the error of run, as it was suspected that the sudden change which always occurred in this quantity on the reversal of the instrument was due to an error in the assumed length of one of them. These observations showed that one of these spaces corresponding to $2'$ on the circle (the arc $45°\ 0'$ to $45°\ 2'$ on Circle B) was $0''\cdot67$ less than the value given for it in Part IV. of the *Dunsink Observations*.

The reductions of the meridian observations, which at the

beginning of the year had fallen very much into arrears, are now in a forward condition. The Right Ascensions up to the end of the year have been all reduced, and the Declinations with but a few exceptions. All the stars of the new working list observed from September 1885 till July 1887 have been reduced to mean place during the year.

In addition, the sheets of Part VI. of the *Dunsink Observations*, which will contain the places of the southern stars mentioned in former reports, have been printed, and are now in the binders' hands.*

During the night of October 12 the South equatorial was employed in observing the occultation of *Regulus* by the Moon, an account of which has been already published in the *Monthly Notices*.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have been confined mainly to observations with the Transit Circle of a list of stars in the earlier volume of Weisse's Bessel, the mean places of which were found not to agree sufficiently well with the mean places of the same stars in the Glasgow Star Catalogue. The observations are now drawing to a close, and it is to be hoped that the results will serve to clear up the question whether the discordances are attributable to proper motion or to some other causes.

The total eclipse of the Moon of January 28, 1888, was observed under favourable circumstances. Fourteen star observations (six disappearances and eight re-appearances) were obtained in connection with M. Döllen's method for correcting the apparent diameter and parallax of the Moon.

The Kew Observatory of the Royal Society, Richmond, Surrey.

The sketches of Sun-spots, as seen projected on the photo-heliograph screen, have been made on 180 days, in order to continue Schwabe's enumeration, the results being published in an Appendix to the Annual Report presented to the Royal Society.

Three hundred and forty-seven observations of solar and 80 of sidereal transits have been taken for the purpose of keeping correct local time at the Observatory, and the clocks and chronometers have also been compared daily.

The following clocks: French, Shelton K. O., Shelton 35, and

* Since this report was written, Part VI. of the *Dunsink Observations* has been issued.

the chronometers: Molyneux, No. 2125, Breguet, No. 3140, and Arnold 86, are kept carefully rated as timekeepers at the Observatory.

The mean-time clock, Dent 2011, has been bolted to the wall of the chronometer-room for use in daily comparisons with the chronometers on trial.

The library of the Observatory has received a present from Wm. J. Davis, Esq., of a MS. volume of Sun-spot observations made at Edmonton, Middlesex, from August 1819 to March 1823. It is intended to enumerate the spots after the Schwabe method, so as to carry the Observatory catalogue of the new groups of Sun-spots back to 1819.

At the request of the Chairman, the MSS. Sun-spot measurements and reductions from February 1862 to December 1863, together with the tables for computing the spotted positions, as well as the Kew working catalogues from 1864 to 1872, have been forwarded to Mr. A. L. Soper for the purpose of further discussion.

The Indian Pendulum Apparatus was put up in the room specially erected for its accommodation in the South Hall of the Observatory, and certain preliminary swings made in the presence of both General Walker and Colonel Heaviside, R.E., which sufficed to show that the apparatus had not undergone any material changes since it left Kew in 1881.

It was, however, found that the vacuum chamber had received such structural damage in transit as to render it incapable of exhaustion to a sufficiently high degree to make the observations comparable with those previously made by Captains Basevi and Heaviside. It was accordingly returned to the maker, Mr. Adie, of London, for thorough repair, and has recently been again erected in its place, and found in a very satisfactory condition, so that the required preliminary observations may now be re-commenced.

By the kindness of Mr. W. H. Preece, F.R.S., the Committee were favoured with the loan of a recording chronograph for use in registering the coincidences. Experience proved that it was unnecessary, and the apparatus has since been returned to the General Post Office.

At the suggestion of Colonel Heaviside, photographs of the invariable pendulums were obtained on their removal from their cases after travelling, in order that a memorandum might be preserved of their figure and shape on their return to the Kew Observatory.

The arrangements for rating watches mentioned in previous reports have been carried on during the year with continued success, and up to the present 1344 watches have been examined and reported upon.

Five hundred and ten entries of watches were made, as contrasted with 490 during the corresponding period of last year,

and it is also extremely satisfactory to note that a very marked increase has taken place in the number of watches which have gained more than 80 marks.

Since the institution of chronometer trials, as mentioned in last year's report, 27 movements have been examined, and certificates issued giving the mean daily rate and variation of rate at each change of temperature.

A Kullberg's temperature regulator has been fitted by the maker to the chronometer oven, and a Richard thermograph is also arranged to work in the case with the chronometers, affording a continuous record of the temperatures which they have experienced during the whole of their trial.

The range of temperature from 55° to 85° F., to which the marine chronometers are submitted, has been decided upon after consideration, as being amply sufficient for determining the behaviour of chronometers under conditions to which they are usually exposed at sea, and no serious objections have yet been received from makers or others to the adoption of the above range.

By the kindness of the Astronomer Royal the Kew Observatory has been favoured with descriptions of the tests applied to Navy telescopes supplied by contractors to H.M. Service, and also descriptions of the apparatus employed at the Royal Observatory, Greenwich, for applying them.

A standard telescope of the Admiralty pattern has been purchased, and the necessary appliances are now being constructed, with the view of enabling the Committee to apply similar tests to telescopes submitted to them for verification by opticians and others.

An addition has also been made to the number of angle-measuring instruments verified, in the shape of range-finders. Several patterns of these instruments, for use both at sea and on shore, have been tested; two additional movable adjustable collimators with scales have been fitted to the sextant testing apparatus, to enable it to be used for the necessary purpose.

The magnetical and meteorological observations and reductions, and also the verifications of instruments, operations to which the attention of the Observatory is more particularly directed, have been still carried on as in former years.

Liverpool Observatory, Bidston, Birkenhead.

The Greenwich mean time, as deduced from observations of stars with the transit instrument, has been communicated to the port daily, Sundays excepted, by the firing of the time-gun placed on the pier-head of the Morpeth dock. No instance in

which the gun has failed to fire has occurred during the past year, and the flash has in each case accurately indicated 1^h P.M., as shown by the clock in the chronometer-room. Daily comparisons of clocks and chronometers have been made as heretofore. All chronometers deposited at the Observatory for the purpose of being tested have had their thermal errors determined by the systematic and symmetrically arranged test, in three definite and equidistant temperatures, devised by the late director of this Observatory. The delicate gas-governor invented by the late Mr. Alfred King enables the required temperature to be maintained within about one degree of Fahrenheit. The officers of the Pacific Steam Navigation Company have been supplied with the probable rates of their chronometers for the ensuing voyage, in each five degrees of temperature from 45° to 95° Fahr., and the records received of the performance of the instruments show the accuracy with which Greenwich time can be carried on at sea under such conditions.

The meteorological work has been conducted as in previous years. No interruption has occurred in the records of the self-registering instruments.

Radcliffe Observatory, Oxford.

The following have been the subjects of observation during the year 1887 :—

With the transit circle :—

1. Observations of stars to the seventh magnitude inclusive between 115° N.P.D. and the equator.

2. Observations of the Moon, which are continued throughout the lunation, and regularly compared with the Right Ascensions and North Polar Distances of Hansen's Lunar Tables. Such comparisons appear to have a special value in keeping distinctly before astronomers the extraordinary character of the change between the results of observation and theory which took place about the year 1864. The mean error in longitude of Hansen's Tables has changed from $-1''{\cdot}61$ in the year 1863·5 to $+15''{\cdot}65$ in the year 1887·5, being at the average of $0''{\cdot}72$ per annum.

3. Observations of the Sun.

4. Reflexion observations of stars.

The following table gives the number of observations made during the year 1887 :—

Transits, 2,820.
Circle observations, 2,290.

These totals include—

Observations of the Moon on 49 days.
Observations of the Sun on 59 days.
19 Reflexion observations of stars.
171 Determinations of Nadir point.
1 Duration of passage of the Moon's diameter.
6 Vertical diameters of the Moon.

With the extra-meridional instruments :—

13 observations of 8 occultations of stars by the Moon.

The Barclay Equatorial has been mounted and brought into regular use. The values of the scales of the micrometers have been determined; and the instrument has been employed in the measurement of double stars, observations of Comet 1887 *e* (Barnard, May 12), and some star-charting.

The volume for 1884 has been printed and distributed.

The volume for 1885 is being prepared for press.

The observations made in 1886 are completely reduced; the N.P.D. reductions for 1887 are complete; the R.A. observations, 1887, are all entered to date and partially reduced.

University Observatory, Oxford.

The work at this Observatory has proceeded steadily on the same lines as those recently adopted, and mentioned in the last report.

The parallax of μ *Cassiopeiæ* has been computed. That of *Polaris* and of η *Cassiopeiæ* will require continued observation until August next, owing to breaks in the continuity of the work caused by alteration and renovation in the De la Rue instrument. A plan is now in progress of execution for determining on one system the parallax of all stars of approximately the second magnitude suitably situated at Oxford. This applies to thirty stars, and may be expected to occupy three years. It has been found that little or no advantage in point of accuracy, and certainly no commensurate advantage, arises from continuing the photographs uninterruptedly throughout the year; in future they will be confined to those periods when the position of the star in the so-called parallactic ellipse shows the greatest and least displacement from each of the four stars of comparison employed.

Much time has been spent upon the examination of two mirrors each of fifteen inches aperture, and of eighty and one hundred and twenty inches focal length respectively, the main object being to ascertain what photographic effects or advantages are due to focal length. This inquiry is undertaken at the request of a Committee of the Royal Society, to whom a report will

in due course be presented. Owing to abnormally unfavourable skies and some defective mechanism, the inquiry has proved very troublesome, but the difficulties, it is now believed, are overcome.

Dr. De la Rue has generously placed a considerable sum of money at the disposal of the Board of Visitors for the provision of a Photographic Telescope, suitable for carrying on the charting work of the heavens, proposed at the recent Paris Conference. The preparations are in the hands of Sir H. Grubb, who, at length, has obtained the discs of glass necessary for the purpose, and the instrument will be completed without delay.

The University has acknowledged Dr. De la Rue's munificence by a formal vote of thanks in Convocation, and has provided the means of carrying on the above photographic work for the next five years. In the vote of thanks, Mr. Barclay and Mr. Nasmyth have been included; the former for the gift of his admirable Transit-Circle, and the latter for his superb Cartoons of Lunar Formations. These latter now utilise and adorn the walls of the Lecture Room of the Observatory, and have been advantageously employed as illustrations in some recent public lectures.

The work of the Observatory has been greatly aided by the ability and perseverance of the two assistants, Mr. Plummer and Mr. Jenkins.

Temple Observatory, Rugby.

During the year 1887 more use has been made of the Observatory by members of the School than in former years, chiefly in the practice of finding the errors of the transit and other instruments, and in correcting observations.

The Observatory has been open on 67 nights, during the greater number of which boys have been present.

The original work has been consequently less than in former years. Mr. Percy Smith has made measures of 50 double stars, and Mr. Seabroke has made 121 sets of measures on 44 different stars with the spectroscope for the detection of motion in the line of sight.

The usual routine work for the correction of clocks has been continued as before.

Stonyhurst College Observatory.

The meteorological, magnetic, and solar work have all been carried on as in preceding years. Solar drawings, 10½ inches to the diameter, have been made on 259 days, spots and faculæ being drawn most accurately to scale; and the chromosphere

has been measured completely 123 times, and partially thrice. Great attention continues to be given to the general examination of the solar surface, and to the study of the different classes of veiled spots. On days on which the definition was exceptionally fine attempts were made to determine the direction of solar surface currents by observing the inclination of the chromosphere filaments and of the lesser prominences. Occasional observations were also made of spot spectra in the region between B and D.

The umbra and penumbra of all the spots of 1886 and 1887 have been measured, expressed in millionths of the visible solar hemisphere, and reduced to curves.

Positions were obtained of Comets Finlay and Barnard; and the assistants of the observatory have taken part in a systematic watch for meteors. The phenomena of *Jupiter's* satellites, and occultations of stars by the Moon, were observed on most favourable occasions.

Several months of the year were principally devoted to collecting and adapting the instruments, and in making photographic experiments, in preparation for the total solar eclipse of August 19, and in the journey to Russia. The chief addition to the instruments of the Observatory was a large heliostat made by Hilger for spectroscopic work.

Mr. Common's Observatory, Ealing.

Considerable progress has been made in the construction of the 5-ft. reflector. The mirror has been polished and figured several times in order to gain experience in the art. There is evidence of internal strain in the glass, which may or may not affect the image, and it is contemplated to order another disc in case this one does not permit of a good final figure.

The mounting is in a forward state, the telescope tube being connected to the polar axis, this latter being a wrought-iron cylinder about eight feet diameter which will float in a tank of water, so as to relieve the friction in the manner mentioned in vol. xliv. of the *Monthly Notices*, p. 367.

The house or covering for the telescope, which will also carry the platform for the observer when the telescope is used as a Newtonian, is framed together and partly erected. It is hoped that the whole will be ready to use in the autumn.

MM. Henry have most kindly just placed at Mr. Common's disposal a fine plane mirror suitable for the telescope when used as a Newtonian.

The Earl of Crawford's Observatory, Dunecht.

During the first and last quarters of the past year the Transit Circle has again been used by Dr. L. Becker on moonlight nights for the observation of comparison stars, and stars within one degree of the pole, while in the absence of the Moon places of the brighter nebulæ have been determined. The latter work has been much facilitated by the introduction of a new frame carrying only seven right ascension wires. The temperature of the transit-room has, with great advantage, been brought nearly down to that of the outer air by enclosing the gas lamps and their long ventilating tubes in roomy casings of bright tin-plate.

Early in the spring plans were worked out for establishing a large spectroscope on the top of a commanding hill, the Barmekin of Echt, about a mile and a half W.S.W. of the Observatory, with a view to laying down the low-sun lines. In the month of May two portable huts were erected on the crown of the hill, in one of which the large Rowland grating was mounted with a collimator and viewing telescope of four inches aperture. As might have been expected, the spectrum, when the sun was near the horizon, showed an immense number of atmospheric lines, especially on the rare occasions when a sufficiently narrow slit could be used at altitudes of less than one degree. As it was necessary to note down both the appearance and position of these lines as quickly as possible, a recording apparatus was brought into use which had been devised in the course of the preceding winter. By its help as many as 540 lines have been recorded in position and thickness in less than an hour. As the interval between sunset and sunrise at midsummer is only six hours, and as it was necessary to identify forthwith the chief lines in each set of observations, complete camping accommodation was provided at the station. So well did this arrangement work, that Dr. Becker, favoured by the unusually fine summer, by remaining on the hill every night succeeded in recording no fewer than forty-eight sunsets or sunrises in the months of June and July. The observations are the more valuable, as about the beginning of August heavy rains set in, and the weather in general was so unfavourable that only two sunrises, and not a single sunset, were observable in that month. Nor did the skies improve much before the end of the year, for in the last ten weeks there were but five nights on which nebulæ could be observed in the meridian, while the fifteen first weeks of the year yielded seventeen nights suitable for that class of work. As at present arranged, the low-sun apparatus can only be conveniently used when the sun is north of the equator, but eventually it is hoped that some typical parts of the spectrum can be observed in the middle of winter. Last year's work was intentionally kept almost entirely between wave-lengths $516{\cdot}5$ and 604^{mmm}.

Within these limits upwards of 13,000 observations have been made, and for them the normal lines are all reduced. 4,500 records of lines have been reduced to the final wave-lengths on the basis of Prof. H. A. Rowland's paper "On the Relative Wave-length of the Lines of the Solar Spectrum," in the *Amer. Journ.* for March 1887.

The large Cooke spectroscope was used by Dr. Copeland on the 15-inch equatorial on twenty-one nights in January to March for measuring the spectra of stars and nebulæ. With it the temperature coefficients of three prisms were also deduced from a long series of readings taken at various temperatures, partly in a heated room. In December a few observations were made with the Grubb stellar spectroscope.

In the course of the year twenty-one circulars were sent out, almost exclusively about comets. As in former years, Dr. Oppenheim, of Berlin, supplied a large part of the computations, and to him the thanks of observers are due.

Very much time has been devoted to the library in checking and revising the titles and descriptions of the books. In May the printing of the catalogue was commenced. About one-third of the work has been passed through the press.

Particulars of Dr. Copeland's journey to Russia for the purpose of observing the total eclipse of the Sun are to be found on p. 48 of this volume.

The weekly firing of the time-gun and the daily meteorological observations have been continued as in former years.

Mr. Crossley's Observatory, Bermerside, Halifax.

As usual at this Observatory, the phenomena of *Jupiter's* and *Saturn's* satellites, occultations of stars by the Moon and transits of stars for time, have been observed whenever the weather and the demands on time made by the reflector permitted. About thirty of the phenomena of *Saturn's* satellites have been observed.

Much time has been devoted to the improvement and adjustment of the equatorial movements of the 3-foot reflector, the completion of the dome, the testing of the large mirrors and flats, the mounting and support of the flats, the art of silvering mirrors, and the mechanical means of handling them with safety, &c.

The A mirror was resilvered in December, and is now in the telescope. It is intended shortly to give a full description of the Observatory and some account in detail of the above work.

Mr. Huggins's Observatory.

During the last year the principal instruments have undergone careful cleaning and repairs. The lenses of the 15″ achro-

matic object-glass, which have remained united with castor oil since 1870, have been separated, cleaned, and again put together with castor oil.

The driving clock has been cleaned, and the driving screw has been recut.

New spectroscopes and other apparatus have been added to the appliances to be used connected with the refractor and the reflector, which are mounted on the same equatorial stand.

These improvements, which have occupied many months, have prevented new work being done beyond the observations necessary for the adjustments of the different instruments.

Mr. C. E. Peek's Observatory, Lyme Regis.

Astronomical observations have been continued during 1887. No repairs or alterations of the building have been required, and the machinery for working the dome and transit shutters remains in perfect order.

One hundred and sixty-five nights were available. The most cloudy month was January, and the clearest August. The year 1887 was therefore more favourable to astronomical work than 1886, in the proportion of 165 to 146 observing nights.

Transit observations for time were taken on all available nights, and both sidereal and mean time chronometers have preserved satisfactory rates.

The mean-time service has been considerably improved by laying a wire and sending an hourly signal from the Standard clock to a Turret clock, which gives G.M.T. to the district.

The subjoined table gives the long-period variable stars under regular observation with the equatorial telescope of $6\frac{4}{10}$ inches aperture, and the number of nights on which each has been observed during the year :—

Star's Name.	Observations.	Star's Name.	Observations.
S Cassiopeæ	18	R Böotis	16
R Piscium	8	S Coronæ	16
R Tauri	6	R Serpentis	13
R Orionis	3	S Herculis	15
T Orionis	19	R Aquilæ	13
R Geminorum	5	R Cygni	15
R Cancri	6	χ^2 Cygni	16
V Cancri	13	S Cephei	17
T Ursæ Majoris	19	R Pegasi	13
S Ursæ Majoris	24	R Cassiopeæ	19

Several of these stars have been under observation since March 1886. The observations are all plotted on a uniform

scale, and as soon as any star has been observed over several complete periods it is proposed to publish a memoir with plates showing the variations in the light curve.

Colonel Tomline's Observatory, Orwell Park, Ipswich.

The work of this Observatory has been confined to the continuous observation of comets. Seven of these bodies in all have been observed during the year, but two of them belong more properly to the previous twelve months. The following table will give most conveniently a summary of this work:—

Name of Comet.	No. of times observed.	Between what dates observed.
Barnard-Hartwig	3	Jan. 2—Jan. 10
	(part of a series of 24 observations)	
Finlay	5	Jan. 12—Feb. 25
	(part of a series of 20 observations)	
Brooks	32	Feb. 12—Apr. 23
Barnard I.	9	Feb. 13—May 20
Barnard II.	9	Feb. 28—Apr. 10
Barnard III.	20	June 9—July 28
Olbers	21	Sept. 12—Dec. 27

Further observations of the last of these are yet hoped for. The reductions have been entirely effected, and the results (those of Olbers's comet excepted) have been communicated to the Society, and published in the *Monthly Notices*, vol. xlviii., No. 1.

As this department of astronomical study is only intermittently taken up elsewhere in England, it will be the aim of this Observatory in future to make the observations as full as possible and to include all comets visible in the northern hemisphere.

Lieutenant-Colonel Tupman's Observatory at Harrow.

The work of determining the places of comparison stars and other selected small stars has been continued with the meridian circle. Observations were made on eighty-two nights, in all 1150 chronographic transits and 1040 observations of N.P.D., all four microscopes being twice read for each circle reading. These observations are completely reduced. The correction for runs has shown no sensible variation since the instrument was mounted. On each night a star was observed below pole for azimuth error, and the level error was determined twice by spirit

level. The collimation error was found on thirty-one days by reversing the instrument and observing the N. collimator, which, with its pillar, having been thickly covered with felt, is much steadier.

By means of the large number of fundamental stars observed, differing considerably in declination on the same night, a preliminary investigation has been made of the errors of division of the circle in terms of the system of declinations of the *Berliner Jahrbuch*, between the zenith and equator, the difference for this interval being 1″.

A few stars passing very near the zenith were observed for co-latitude, the result being identical with that previously obtained.

The observing list for the meridian circle now contains all the comparison stars used by Mr. Plummer for his recent comet observations (*Monthly Notices*, vol. xlviii. No. 1), many of Mr. Bryant's in connection with *Sappho* and two or three hundred other stars.

The Equatorial comparisons of comets, &c. have all been published in the *Monthly Notices*.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets.

The following seven minor planets were discovered in the year 1887:—

No.	Name of Planet.	Date of Discovery, 1887.	Discoverer.	Place of Discovery.
265	Anna	Feb. 27	Palisa	Vienna
266	Aline	May 17	„	„
267	Tirza	May 27	Charlois	Nice
268	Adorea	June 9	Borrelly	Marseilles
269		Sept. 21	Palisa	Vienna
270	Anahita	Oct. 8	Peters	Clinton
271	Penthesilea	Oct. 16	Knorre	Berlin

Minor planets Nos. 262 and 263, both discovered by Herr Palisa on Nov. 3, 1886, have been named *Valda* and *Dresda* respectively.

The Comets of 1887.

The following six comets have been discovered during the year 1887; brief notices of each are given in the order of their discovery.

Comet I., 1887.—The great Southern Comet, first seen with the naked eye at several places in the southern hemisphere, in the third week of January. Its appearance resembled that of Comet I., 1880, and it is one of a group of comets, all with short perihelion distances, of which other members are known as 1843 I., 1880 I., and 1882 II., and among which may possibly be included Pogson's Comet of 1872, and the one visible at the time of the solar eclipse, 1882, May 16.

Its appearance is described at Cape Town as presenting no observable condensation, and having a band of light 35° long, narrowing towards the Sun. The observations are, in con-

sequence of the absence of any observable nucleus, very rough, and extend over such an inconsiderable interval of time that the determination of the orbit (which has been attempted by Mr. Finlay and Dr. Oppenheim) is very unsatisfactory, but it possesses sufficient exactness to show the similarity of the elements with those of the comets mentioned above.

The comet was not seen in the northern hemisphere; a suspicious observation, recorded by Mr. Lewis Swift, of Rochester, does not appear to refer to this comet.

Comet II., 1887.—On January 22, a faint comet was detected by Mr. Brooks, of Phelps, N.Y., in the constellation *Draco*, and which passed through its perihelion about the middle of March, but at a considerable distance from the Sun (1·633), and consequently, though observations were possible for a considerable period, it never attained any great brilliancy. The comet was observed as late as April 23, when it possessed a theoretical brilliancy of less than one-half that which it had at the time of discovery. The observations are well represented by a parabola, and very approximate elements are given by Dr. Oppenheim, *Ast. Nach.*, No. 2,780.

Comet VIII., 1886.—This comet was discovered by Mr. Barnard, of Nashville, on the following evening, January 23, but as the perihelion passage occurred in the previous November it is referred in the catalogues to that year. The brightness was rapidly diminishing at the time of discovery, but observations were continued till the middle of May, and as in the case of the last comet, these observations are well represented by a parabola.

Comet III., 1887.—Also a parabolic comet discovered by Mr. Barnard on February 16, 1887. This comet was very faint and offered no central condensation, and does not appear to have been very frequently observed. Very approximate elements are given by Dr. Oppenheim in *Ast. Nach.*, No. 2,777.

Comet IV., 1887.—Was also discovered by Mr. Barnard, on May 12, at a considerable southern declination. This comet had a faint tail preceding, and a faint nucleus, estimated at Algiers to be of the twelfth magnitude. The comet was moving rapidly to the north so as to become an easy object in northern observatories, and throughout the month of June and part of July could have been observed with meridian instruments. The gradual diminution of the light prevented observations after the middle of August. The deviation from parabolic motion is probably very slight, but the definitive discussion of the orbit has been undertaken by Dr. Muller, of the McCormick Observatory, Virginia.

Comet V., 1887.—Better known as the reappearance of Olbers's Comet of 1815, the return of which was to be expected from the careful computations of Dr. Ginzel. The comet was first seen by Mr. Brooks on August 24, though its identity with that of Olbers was not then suspected. It was tolerably bright, with traces of nucleus and tail.

The extensive ephemerides which Dr. Ginzel had prepared

with the view of aiding its discovery and recognition showed at once that the earliest observations corresponded to a true anomaly of about −40°, and, therefore, that the perihelion passage would occur early in October, and that consequently the most probable period given by the calculations was only about 290 days in error, or less than half the amount which Dr. Ginzel thought possible. The period is about 72·6 years, but the definitive determination of the elements will be still further pursued by Dr. Ginzel.

The greatest brilliancy of the comet was reached about Oct. 10, and though the light is now only about one-third of that the comet had at the date of its discovery, it is to be hoped that it is still within observation of some of the larger telescopes.

W. E. P.

The Transit of Venus, 1882.

The Committee appointed by the Government to superintend the Transit of *Venus* 1882 expeditions has presented its report, which, with the exception of a short introduction enumerating the stations selected by the Committee, the *personnel*, and acknowledging obligations to institutions, Governments, and individuals who had rendered assistance, consists entirely of the discussion of the observations of contact by Mr. Stone, the Directing Astronomer.

In addition to the observations made by the Government expeditions to Madagascar, Barbadoes, Jamaica, Bermuda, and New Zealand, the report includes observations made at Mauritius (1 obs.); Durban, Natal (1); Cape of Good Hope (10); Strait of Magellan (3); Cambridge, Mass. (2); Kingston, Canada (2); Ottawa (2); Cobourg (1); Winnipeg (1); Hobart (1); Melbourne (2); Wentworth, N.S.W. (1); New Zealand (14); so that for the internal contact at *ingress* there are 24 observations and for the same phase at *egress* 32 observations.

For *ingress* four more or less distinct phases, spread over a minute of time, appear to be recognised. The second of these phases, corresponding to a distance of the centres of the Sun and *Venus* of 941″·4, is believed to be identified in eleven reports, and these give for the solar parallax

$$8''{\cdot}874 \pm 0''{\cdot}081.$$

The 24 observations of the third phase, corresponding to a distance of centres of 939″·8 (which was the principal phase according to the instructions issued by the Committee), give for the mean solar parallax

$$8''{\cdot}823 \pm 0''{\cdot}023.$$

For the *egress* two phases appear to be recognised—

(1) Haze or shadow.

(2) Limbs obscured, or geometrical contact.

But, at many of the stations, only a single time had been given as that of internal contact, and it became therefore necessary to select from the two times given at the other stations a time of internal contact to be combined with the times recorded for internal contact at the stations where only one time was given.

Three solutions have therefore been given—

First, by taking the times recorded for "haze or shadow" for combination with the single recorded times for internal contact at the other stations the resulting value is

$$\pi = 8''{\cdot}827 \pm 0''{\cdot}050.$$

Secondly, by taking the times recorded for "limbs obscured, or geometrical contact," for combination with the single recorded times for internal contact the resulting value is

$$\pi = 8''{\cdot}882 \pm 0''{\cdot}043.$$

Thirdly, by taking the mean of the two recorded times as that which best represents, in the mean, the time of internal contact which would have been assigned had the observers at all stations restricted themselves to a single time of internal contact the result obtained is

$$\pi = 8''{\cdot}855 \pm 0''{\cdot}036.$$

And this is considered in the report as the best result obtainable from the *egress* observations.

When the results from *ingress* and *egress* are combined, the effects of any small outstanding errors of relative differences in R.A. and N.P.D. are sensibly eliminated, and the resulting value is

$$\pi = 8''{\cdot}832 \pm 0''{\cdot}024.$$

The report contains no details of time observations or of determinations of longitudes. And, as the results of some new and accurate longitudes are here made known, it is to be hoped that the details may be soon published. The report is silent on the subject.

The Total Solar Eclipse of August 19, 1887.

The total solar eclipse of August 19, 1887, will long be remembered as an occasion on which the most extensive preparations on the part of observers were only attended by the most widespread disappointment. At eight German stations, thirteen Russian, and one Japanese, representing more than double this number of observers, the sky was quite cloudy during

totality. Fine weather, apparently quite local, favoured only the following stations:—

(1) A village on the Moscow railroad, where Prince Gagarin photographed the corona.

(2) Elpatievo Narischkine (longitude $2^h\ 32{\cdot}5^m$ E., latitude 56° 58′ N.), where Mr. Il. Urech made eye-observations of the corona and prominences, of which four were seen.

(3) Petrowsk, where Professor Glasenapp obtained seven sketches and two photographs of the corona, thin cloud preventing his proposed search for *Vulcan*. Photographs of the corona were also obtained by Kowalsky and Tatschaloff, of St. Petersburg, and Stanoiewitsch, of Meudon, and of the spectrum by Professor Kononovitsch, of Odessa.

(4) Jurjewitz, where in bad weather Dr. Niesten made a drawing of the corona and secured six good photographs; and Mr. Karelin with his 6-inch portrait lens also obtained a very good photograph.

(5) At Mount Blagodat, in the Urals, Dr. Handrikof made some good drawings of the corona and prominences.

(6) Krasnojarsk, where sketches and photographs were obtained by Chamontoff and party.

(7) At Irkutsk a good photograph of the corona was obtained.

(8) In Japan (Echigo) three good photographs of the corona were obtained by Professor Jarai and Mr. M. Sugiyama.

A very complete organisation, under Professor Struve's direction, of stations on the north and south boundaries of totality for determining the ratio of the diameters of the Sun and Moon by observations of the second and third contacts ended only in failure owing to the weather.

The drawings of Dr. Handrikof and the Japanese photographs agree more closely than previous results would lead us to expect. No particulars of orientation are given, however, and the internal evidence not even being consistent, some assumption must be made for the interpretation. The most plausible seems to be that Dr. Handrikof's first drawing (of Baily's beads just before totality) was made with the naked eye, and is erect; while the subsequent drawings of the corona were made with a telescope, and are inverted. The top of the photographs and first drawing then correspond to the north point, and not to the vertex. If this assumption be correct, the coronal extension was greater in the southern hemisphere than in the northern, the principal ray extending from the south-west limit for at least a diameter, as shown in both photographs and drawing. A long though rather low-lying group of prominences was situated at the base of this ray. A fine prominence is shown almost due east, and three others in the north-east. On the east of the Sun are two of the well-known conical masses, composed of rays curving towards each other.

As regards physical observations, nothing has yet been published, except that the single photograph of Prof. Kononovitsch shows the coronal green line.

Sir George Airy's Numerical Lunar Theory.

This work is offered by its distinguished author not as a complete theory of the motions of the Moon, but rather as an examination of Delaunay's lunar theory, as tested by the substitution of numbers for symbols throughout. Delaunay, in his great work, expresses the value of the Moon's longitude and latitude, and also the reciprocal of the radius vector, analytically in terms of certain constant quantities which can only be determined by observation, such as the ratio of the mean motions of the Sun and Moon, the mean eccentricity and inclination of the Moon's orbit, the eccentricity of the Sun's orbit, and the ratio of the Moon's mean distance to that of the Sun. Besides these quantities there are two others which, although they are capable of being found by theory, and have been actually so found with a considerable degree of accuracy, are practically found from observation extending over a long interval of time. These latter quantities are the mean motions of the Moon's perigee and node respectively.

Now, it is evident that if Delaunay's symbols be replaced by the numbers for which they stand, both in the coefficients of the several equations and in the rates of motion of the various arguments, the numerical expressions so formed ought to satisfy the three differential equations of motion identically, provided that Delaunay's solution be sufficiently accurate.

The first part of the present work consists in the carrying out of the above-mentioned substitutions in the differential equations. The operations are necessarily of very great length, and are arranged in the orderly manner to be expected from the author, and every care appears to be taken to ensure accuracy. Notwithstanding this, the author is greatly disappointed with the results. Instead of the equations being nearly satisfied, as was expected, very large discordances showed themselves, more especially in the two equations relating to motion parallel to the plane of the ecliptic, and the author is led to fear that the discordances may be caused by errors on his own part.

It has been pointed out, however, in a paper in the *Monthly Notices* for June 1883, that Delaunay has found the analytical expression for the reciprocal of the radius vector with a far less degree of accuracy than in the case of the Moon's longitude and latitude. In the two latter coordinates he has taken into account generally the terms of the 7th order, and in cases where the convergence of the series is found to be slow, he has included terms of the 8th and 9th orders. In the reciprocal

of the radius vector, however, he has confined his attention to the 5th order. Consequently, while the coefficients of the inequalities in longitude and latitude as found by him are generally only a small fraction of a second in error, the inequalities in the reciprocal of the radius vector are not found with sufficient precision to give even the parallax itself with all the accuracy which is desirable. The neglect of Delaunay of all terms in the parallax of orders higher than the 5th is quite sufficient to account for the discordances noticed by the author, without supposing his own work to be in error.

The second part of the work has for its object to correct the numerical values of the coefficients of the several inequalities as found from Delaunay, by giving to each coefficient an indeterminate variation, and then supposing, as we may do, that the powers of such variations above the first may be neglected, by forming the corresponding expressions for the additional terms thus introduced into the several equations, and thus obtaining a great number of simple equations between those indeterminate variations, by the solution of which their values may be found. This part of the work is far less completely done than the former.

The final equations for the correction of the coefficients are confined to the first 100 arguments in each of two series, the first of which belongs to motion parallel to the plane of the ecliptic and the second to motion perpendicular to it.

To make the work complete many more of the equations should be taken into account.

Since the errors affecting Delaunay's coefficients of parallax are comparatively large, it will be necessary to determine the factors by which these errors are multiplied in the equations of condition with a much greater degree of accuracy than is required in the case of the factors by which the errors of the coefficients of longitude and latitude are multiplied in the same equations. Otherwise it will not be possible to deduce these last-mentioned errors from the equations with the requisite degree of precision.

This has been already pointed out in the paper above referred to, and, as is there stated, it will be necessary to take special precautions in order to determine with accuracy the corrections of the assumed coefficients in the inequalities of longitude which have long periods. On the other hand, in the case of inequalities whose periods are not greater than about one half the Moon's periodic time, the equations for finding the corrections required by the coefficients of longitude and reciprocal of radius vector are very distinct from each other, so that each of these corrections may be found by means of a large divisor, and therefore the results will be little affected by small errors or omissions in the calculations.

Thus the solutions given by Sir George Airy in his Section X. for the equations which admit of large divisors are fairly satisfactory.

It is quite otherwise in the case of inequalities of radius vector and longitude, the periods of which are either nearly equal to the Moon's periodic time, or are much greater than that period. In both these cases, the corrections required have to be found by means of a very small divisor, so that a small error of calculation or of omission will be much magnified in the result.

In these cases the author simply adds together the pair of equations from which the corrections of the corresponding coefficients of longitude and radius vector are to be determined, and thus forms one final equation, and he is driven to supply the second equation by the wholly inadmissible assumption that the correction required by the coefficient of the reciprocal of radius vector is twenty-five times as great as that required by the corresponding coefficient of longitude.

It would be more accurate to assume that the errors of Delaunay's equations of longitude are zero, and to use the single final equation obtained in the way just mentioned in order to obtain the corrections required by the corresponding coefficients of parallax.

It may be remarked that the coefficients of parallax thus found agree very well with those given in the paper in the *Monthly Notices* of June 1883, which has been already mentioned.

J. C. A.

Professor Auwers's Investigation of the Sun's Diameter.

A very complete investigation of the value of the important constant of the Sun's diameter, obtained by meridian observations, has been made by Professor Auwers, and published in the *Sitzungsberichte* of the Berlin Academy.

The results for the horizontal and vertical diameters are derived from a discussion of the following observations: (1) A long series of thirty-three years' observations made with the Greenwich transit circle, 1851 to 1883; (2) Washington transit circle observations, 1866 to 1882; (3) Oxford (Radcliffe) observations, 1862 to 1883, with the exception of the years 1877 to 1879; and a series of Neuchatel observations, 1862 to 1883.

In discussing the Greenwich observations Professor Auwers gives in two tables the mean annual correction to the horizontal and vertical diameters for each observer from 1851 to 1883. The personal equations are determined, first, on the supposition that the Sun's diameter may be variable; and, finally, on the view that the mean annual diameter is constant, and that the personal equations may be liable to change. The personal equations are referred to the mean of the four observers, Dunkin, Ellis, Criswick, and Carpenter, who made the larger part of the observations, with the following results:—

Horizontal diameter	$32'\ 2''\cdot48$	3114 Observations.
Vertical diameter	$32'\ 2''\cdot00$	3289 „

The results of the Greenwich observations referred to the mean observer give—

Horizontal diameter	32′ 2″·01
Vertical diameter	32 2·73

A reduction of the heliometer observations made by the German Transit of *Venus* expeditions gives a value for the Sun's diameter of 31′ 59″·12. These observations were made with object-glasses of about 3 inches diameter, and the results do not differ materially from those made with the Königsberg 6-inch heliometer. The author therefore assumes provisionally the value 31′ 59″·12 as an absolute determination of the solar diameter with which to compare the Greenwich results. And in an interesting table he gives the personal equations for the two diameters of the 67 Greenwich observers, their absolute errors, and the differences of the two observed diameters. It is significant that all the errors for both horizontal and vertical diameters are positive, and in the column H−V it is equally noteworthy that the sign in the majority of cases is negative.

The Washington observations are discussed in a similar manner to those of Greenwich, and yield the following results:—

Horizontal diameter	32′ 2″·41	1321 Observations.
Vertical diameter	32 2·65	1297 ,,

A similar determination of the personal equations and absolute errors of the 15 Washington observers is made as in the case of Greenwich, and with a similar result; all the errors for both horizontal and vertical diameters are positive.

The final results obtained for the mean values of the Sun's (assumed circular) diameter, from each series of observations, are—

Greenwich	32′ 2″·36	Oxford	32′ 3″·19
Washington	32 2·51	Neuchatel	32 3·27

The conclusion from this discussion arrived at by Professor Auwers is that the determination of the Sun's diameter by meridian observations is largely affected by personal equations, which may amount to 4″ or 5″; and further, that for the investigation of any ellipticity in the Sun's disk, it would be preferable to employ the heliometer.

The second portion of Professor Auwers's paper is devoted to the subject of the alleged annual variation of the Sun's diameter; the conclusion arrived at being that such variation has no real existence, and that the apparent differences are due in a great measure to the influence of temperature on the instruments.

This investigation of Professor Auwers is of very high

importance, as it gives us the most reliable value of the solar diameter which the best meridian observations are capable of affording.

The Catalogue of the Paris Observatory.

On becoming Director of the Paris Observatory in 1854, Le Verrier resolved to undertake the re-observation of Lalande's catalogue of 47,390 stars; and as he considered it of primary importance that at least three observations in both right ascension and declination should be secured, the task proposed was of a gigantic character worthy of that illustrious astronomer.

Up to the year 1879 only about one-third of the necessary observations had been secured, including the previous observations made since 1837 under the direction of Arago, and the average number of meridian observations made annually was about 6,000 to 8,000. Since then the instruments of the observatory have been increased by the Bischoffsheim Meridian Circle, and through the active directorship of Admiral Mouchez the observing staff has been augmented, so that for the past seven or eight years the number of observations secured annually towards the preparation of the catalogue has amounted to the remarkable number of 25,000 to 28,000.

It was not considered desirable to delay publication until the whole of the stars had been observed, and therefore the first part now publishing is limited to stars observed up to the year 1881, which form about three-fourths of the whole number: the observations subsequent to 1881 will be published in a separate volume.

The first instalment of this important catalogue has just been published in two handsome volumes, one being devoted to the catalogue and the other to the individual observations. The portion of the catalogue published consists of stars in the first six hours of right ascension observed during the years 1837 to 1881. It contains 7,245 stars, and represents 80,000 observations in both elements.

As the observations extend from 1837 to 1881, they are divided into three distinct periods—1837–1853, 1854–1867, and 1868–1881—the observations of each period being reduced to their mean epochs respectively, 1845·0, 1860·0, and 1875·0, thus forming three separate catalogues. All the stars are arranged in the catalogue in the order of their right ascension for 1875·0.

The catalogue gives the number of observations in each of the three periods, the mean date, the R.A., and N.P.D. for each epoch, precessions for 1875·0, and comparison of each catalogue 1845·0, 1860·0, and 1875·0 with Lalande.

As a very large proportion of the observations were made with the transit instrument and the mural circle (meridian

circles having been mounted only in 1863 and 1877), it has resulted that in many cases the number of observations of a star secured in right ascension is disproportionate to the observations in N.P.D. Many of such stars will be re-observed and the results published in a supplementary catalogue.

The reduction of the observations has been conducted under the superintendence of M. Gaillot, who contributes an interesting discussion of the value of the results.

The introductory chapters contain a comparison of the Paris Catalogue with Auwers's re-reduction of Bradley. M. Bossert furnishes a valuable investigation of the proper motions of 374 stars in the catalogue, and he also supplies a long list of errors in Lalande.

The importance of this catalogue to astronomers cannot be over-estimated, and the Paris Observatory is to be congratulated on this indication of the eminently satisfactory manner in which the work has been carried out.

The Dunsink Catalogue of 1,012 *Southern Stars.*

The sixth part of the Astronomical Observations made at the Dunsink Observatory is devoted to a catalogue of the mean places of 1,012 Southern Stars made with the meridian circle, which has been prepared by the Assistant Astronomer, Mr. Rambaut.

Nearly all the stars are contained in the *Southern Durchmusterung Belt* — 2° to — 23° declination, which had been suggested by Prof. Schönfeld and Prof. Peters as needing observation.

The observations were commenced in September 1881 by Dr. Dreyer, and continued by him till May 1882. Mr. Rambaut's observations comprise the period November 1882 to September 1885. The standard stars employed are those of the Berlin *Jahrbuch*, and the observations are reduced to Auwers's system. Most of the stars appear to have been observed only once or twice, and the observations available for the calculation of the probable error are few. A systematic difference is suspected in the right ascensions of the two observers, inasmuch as Dr. Dreyer observed with the eye and ear method, and Mr. Rambaut with the chronograph. The catalogue gives the mean right ascensions and declinations, with the annual precessions, for the epoch 1885·0, the *Durchmusterung* magnitudes, the mean epoch and the number of observations. The separate results for all the observations are contained in the volume.

Heliometer Determination of the Relative Places of the Principal Stars of the Pleiades.

Dr. Elkin has published in the first volume of the *Transactions of the Astronomical Observatory of Yale University* an important investigation of the relative positions of the stars of the *Pleiades* group made by means of the Repsold heliometer of that observatory, which has an object-glass of about 6 inches aperture and rather more than 8 feet focal length.

Taking into consideration the fact that the heliometer determines the relative distance and position-angle of two stars by essentially different means and with considerably different accuracy, the probable error of a distance being much less than of a position-angle, the author resolved to make his determination rest as far as possible on measurements of distance only.

The plan adopted was as follows:—"Near the outer limits of the group four stars were chosen so that nearly the entire group would be enclosed as symmetrically as possible by the quadrilateral they formed, and as their relative positions were to be determined with the greatest possible accuracy, they were taken within direct measuring range of the heliometer. The determination of the place of each star in the group was then to consist of measurements of its distance from each of these four reference points, each such measure giving, it will be seen, an equation involving corrections to an assumed place of the star and the scale value of the heliometer, we would thus have four equations with three unknown quantities, all of which in case the star lay well within the quadilateral could be determined with accuracy." The plan of the work was subsequently modified, and the author concluded to carry out in addition a plan of triangulation similar to Bessel's—namely, measurements of distance and position-angle from η *Tauri* (*Alcyone*), the central star of the group.

The work, therefore, consists of two independent triangulations, one resting upon the four stars enclosing the group, and the other upon the central star *Alcyone*. Unfortunately the two triangulations were not executed simultaneously, the mean epoch of the second falling about a year later than that of the first.

All the observations were made with an eyepiece magnifying 330 times, and with a direct-vision reversing prism placed before it; by means of screens the two stars were reduced to within one-half magnitude of equality. A complete discussion is given of the division errors of the scales, the determination of the scale value, and reduction of the measures of distance and position-angle. Paragraph 8 is devoted to the measures of the distance and position-angles of the *Pleiades* stars from *Alcyone*, and gives a table of the differences of Right Ascension and Declination from that star, and the absolute places of 68 stars for

the epoch 1885·0. Paragraph 9 gives the measures of distances of the *Pleiades* stars from the four stars of the fundamental quadrilateral, with their complete reduction.

In paragraph 11 the author gives the comparison and combination of the two measurements and the deduction of the definitive results. From the discussion it appears that for all distances the probable error is sensibly the same; but the magnitude of the star has had a large effect, and the same thing is noticeable in the probable error of the position-angles; thus—

Magnitude.	Probable Error of one Observation of Distance.	Probable Error of one Observation of Position-angle.
	″	″
3·0 to 7·5	± 0·148	± 0·177
7·6 „ 8·1	0·169	0·236
8·2 „ 8·8	0·223	0·289
8·9 „ 9·2	0·276	0·378

From this it appears that the mean ratio of probable errors is 0·77, or the relative weight of one observation of position-angle is but 0·59 of that of one of distance. The comparison of the two triangulations arranged in magnitude groups indicates that the measures of the four quadrilateral stars from *Alcyone* which serves to unite the two systems are still capable of improvement. The final results are given in a catalogue of 69 stars, giving the right ascension, declination, precession, and secular variation for the epoch 1885·0.

The following sections of the memoir contain a discussion of the Königsberg heliometer measures on the view that the temperature coefficient of the screw value used by Bessel was erroneous; these observations are therefore newly reduced and brought up to 1885·0 for comparison with the Yale results. This comparison is well exhibited by a chart of 32 stars of the *Pleiades*, showing the apparent displacements that result. A remarkable fact is brought out in this comparison—namely, that for the six stars giving the largest values Y–K there is a community of direction and amount; thus:—

Star.	Displacement in R.A.	Displacement in Decl.	Resultant.
		″	″
14	−1·43	+2·15	2·52
17	−2·67	+1·28	2·76
21	−1·31	+1·32	1·78
26	−1·80	+1·16	2·01
35	−1·32	+2·23	2·54
36	−1·91	+1·19	2·12

—the inference being that these six stars do not belong to the group, but are projected on it. Of the remaining 26 of the

32 stars, six stars have an easterly motion, while 20 move towards the west.

Dr. Elkin's valuable memoir concludes with a comparison of his results with the micrometrical determinations of the *Pleiades* made by Wolf at Paris and by Pritchard at Oxford. The deduction from this is, that the use of the filar micrometer for such large distances as those under consideration is likely to be accompanied with considerable casual error and, unless great care be taken, with large systematic error; and the conclusions as to the relative motions in the group advanced in the two memoirs referred to are not supported by the Yale results.

The International Astrophotographic Congress, 1887.

The Congress which assembled at the Paris Observatory on April 16, in response to the invitation of the Académie des Sciences, was attended by the following 56 delegates and representatives of different countries:—

France (20). MM. Baillaud, Bertrand, Bouquet de la Grye, Cloué, Cornu, Faye, Fizeau, Gautier, Paul Henry, Prosper Henry, Janssen, Laussedat, Liard, Loewy, Mouchez, Perrier, Rayet, Tisserand, Trépied (Algiers), and Wolf.
England (8). MM. Christie, Common, Gill (Cape Colony), Knobel, Perry, Roberts, Russell (Australia), and Tennant
Germany (6). MM. Auwers, Krueger, Lohse, Schoenfeld, Steinheil, and Vogel.
Russia (3). MM. Donner, Hasselberg, and Struve.
Holland (3). MM. Bakhuyzen, Kapteyn, and Oudemans.
Austria (2). MM. Eder and Weiss.
Sweden (2). MM. Dunér and Gyldén.
Denmark (2). MM. Pechüle and Thiele.
Belgium (1). M. Folie.
Italy (1). M. Tacchini.
Spain (1). M. Pujazon.
Portugal (1). M. Oom.
Switzerland (1). M. E. Gautier.
America (3). MM. Elkin, Peters, and Winterhalter.
Brazil (1). M. Cruls.
Argentine Republic (1). M. Beuf.

[Of the above, Messrs. Common, Knobel, and General Tennant were delegates from this Society, and this is in substance the report made by them to the Council on their return.]

The Conference was opened by M. Flourens, the Minister for Foreign Affairs, who expressed a cordial welcome to the members in the name of the French Republic, and assured them of the

sympathy and co-operation of the Government in the work they might decide to undertake.

The Conference was conducted under the following Bureau:—

Honorary President: Admiral Mouchez.
Acting President: M. Otto Struve.
Vice-Presidents: MM. Auwers, Christie, and Faye.
Secretaries: MM. Bakhuyzen and Tisserand.
Assistant Secretaries: MM. Dunér and Trépied.

The following general resolutions, which had been printed in a provisional programme, were first taken into consideration and adopted *unanimously*:—

I. The progress made in astronomical photography demands that the astronomers of the present day should unite in undertaking a description of the heavens by photographic means.

II. This work shall be carried out at selected stations, and with instruments which should be identical in their essential parts.

III. The principal objects are: α. To prepare a general photographic chart of the heavens for the present epoch, and to obtain data which will enable us to determine with the greatest possible accuracy the positions and the brightness of all the stars down to a given magnitude (the magnitudes being understood in a photographic sense to be defined). β. To be able to utilise in the best way, both at the present day and in the future, the data obtained by photographic means.

To facilitate the work of the Congress it was decided that a Technical Committee be appointed to consider and report upon the form and size of the instruments to be used, and the least magnitude of stars which it was desirable to photograph on the plates. This Committee consisted of MM. Auwers, Bakhuyzen, Christie, Common, Dunér, Fizeau, Gill, Paul Henry, Janssen, Kapteyn, Loewy, Peters, Rayet, Roberts, Struve, Tacchini, Thiele, Vogel, and Weiss.

The Committee met on April 18 under the presidency of M. Struve, with M. Loewy as secretary. It was unanimously resolved that the *refractor* was the best form of instrument to be employed, and that the dimensions of the photographic equatorial at the Paris Observatory were the most suitable. It was also unanimously resolved that stars be photographed to the 14th magnitude. This decision of the Committee was in a great measure guided by a statement made by M. Paul Henry, that with his telescope of $0^{m}{\cdot}33$ aperture it required an exposure of about 15 minutes to obtain images of stars of about the 14th magnitude, and that to obtain one magnitude lower on the plates the exposure would be $2\frac{1}{2}$ times longer.

The actual recommendations of the Committee finally adopted by the Conference are—

1. The instruments employed shall be exclusively refractors.
2. The stars shall be photographed to the 14th magnitude inclusive, this magnitude being expressed provisionally on the scale actually in use in France, and with the reservation that its photometric value shall be definitely fixed later.
3. The aperture of the object-glass shall be $0^m{\cdot}33$, and the focal distance about $3^m{\cdot}43$, so that 1′ of arc is represented approximately by $0^m{\cdot}001$.

With regard to the above resolutions it should be remarked that M. Steinheil insisted, that in order to have identical instruments, great care should be taken in the selection of the glass, and that the Conference ought to indicate not only the quality to be used, but also the manner in which the objective should be constructed.

The Congress decided to discuss the details of the work in two sections—one *Astrophotographic*, under the presidency of M. Janssen; and the other *Astronomical*, under M. Auwers.

Astrophotographic Section.

The recommendations of this section were accepted *unanimously* by the Congress. They are as follows:—

1. Directors of observatories will be free to have their object-glasses made by any optician they desire to employ, provided they comply with the general conditions laid down by the Congress.
2. The corrections for spherical and chromatic aberration of the object-glasses shall be calculated for rays in the neighbourhood of G of Fraunhofer's scale.
3. The above resolution with regard to the corrections for spherical and chromatic aberration of the object-glasses shall be understood thus: the minimum focal distance shall be that of a ray near G, so as to secure the maximum sensitiveness on the photographic plates.
4. All plates shall be prepared according to one formula to be subsequently determined.
5. A permanent supervision shall be kept over the plates with regard to their relative sensitiveness to different rays.
6. The questions of the preservation and reproduction of the photographic plates cannot be settled now, and it is desirable to refer them for investigation to a special committee.
7. The same course is adopted for the question of the determination of the photographic magnitudes of stars.
8. The object-glasses shall be constructed in such a manner that the available field shall have a radius of at least 1°.
9. In order to eliminate any spurious stars, and to guard

against the inconvenience of minute specks on the plates, two series of plates shall be taken for the whole heavens.

10. The two series of plates shall be so taken that a star situated at the corner of a plate of the first series shall be as near as possible to the centre of a plate of the second series.

With regard to the preparation of the photographic plates, the opinion was strongly expressed upon the great desirability of all the plates being made by the same manufacturer, but this was considered impracticable. MM. Henry, Cornu, and Eder had made many experiments with plates made by different manufacturers, and they were agreed that the differences they found were, as a rule, in sensitiveness only, and not in the maximum sensibility to particular rays.

On this subject the following proposition was made by MM. Dunér, Eder, Hasselberg, Lohse, Tacchini, Vogel, and Weiss: "With regard to the selection of the photographic plates, we suggest that, in addition to the experiments which will be made with ordinary gelatino-bromide of silver plates, there should also be some experiments with plates rendered sensitive to the less refrangible rays of the spectrum by means of colouring matters."

These questions, as well as other suggestions made to the Conference, have been dealt with since by the Permanent Committee.

Astronomical Section.

The recommendations of this section, which were adopted by the Congress, were as follows:—

1. Besides the two plates which should give all stars in the chart of the heavens down to the 14th magnitude, there shall be taken another series with a shorter exposure, in order to secure greater precision in the micrometric measurement of the reference stars and to render possible the construction of a catalogue.

2. The supplementary plates destined for the construction of the catalogue shall contain all stars to the 11th magnitude inclusive. The Permanent Committee shall regulate the proceedings so as to ensure that this condition be fulfilled.

Dr. Schoenfeld estimated that the total number of stars down to 11·5 magnitude would be about $3\frac{1}{4}$ millions.

3. Each photographic plate intended for the catalogue shall be accompanied by all the data necessary for orientation and for the determination of its scale value; as far as possible these data should be found inscribed on the plate itself.

Every plate of this kind shall bear a copy, carefully centred, of a system of reference lines derived from a *réseau*, and intended to eliminate the errors which might be produced by an after distortion of the sensitive film.

Other questions relating to the data contained on the plates will be decided by the Permanent Committee.

4. In the construction of the plates destined to form the chart, the number of auxiliary comparisons intended for the

verification and reduction of the plates shall be reduced to a minimum.

5. The tubes of the photographic instruments shall be made of the most suitable metal for securing an unvarying focal plane, and they shall carry a scale for the determination and adjustment of the position of the plates.

6. The selection of fundamental stars, as well as the question of the formation of a provisional catalogue for the chart of the southern hemisphere, is referred to the Permanent Committee.

7. The question of the mode of measurement, and of the conversion of the numbers obtained into Right Ascensions and Declinations for the equinox 1900, is referred to the Permanent Committee.

The Committee shall in the first place take into consideration the employment of measuring instruments capable of giving, as may be desired, rectangular or polar co-ordinates, and based upon the simultaneous use of scales for long distances and a micrometer eyepiece for the subdivisions of the scale.

It will be seen that the Congress confined its resolutions as far as possible to general principles, leaving the details to be settled by the Permanent Committee. The opinion was expressed that it might be two years before the work could begin generally, and during that time it was reasonable to expect many photographic and optical improvements to be made.

The Congress resolved that the Permanent Committee should be formed on the following principles:—

"The Permanent Committee shall consist of two categories of members.

"(1) All Directors of observatories who will take practical part in the work.

"(2) Members not necessarily taking a direct share of the work."

It was resolved that the second category should be limited to eleven members. The following were elected:—

Christie	Janssen	Tacchini
Dunér	Loewy	Vogel
Gill	Pickering	Weiss
Henry (Prosper)	Struve	

On the subject of other branches of celestial photography than those pertaining to the chart the following resolution was adopted by the Congress:—

"The Congress deems it necessary that there should be a special committee devoted to other branches of astronomical photography than those relating to the chart, considering their importance and the relation which it is expedient to establish between these branches of research. This committee should

place itself in communication with the committee of the chart. The Congress expresses the hope that MM. Common and Janssen would undertake the fulfilment of this wish."

This practically terminated the work of the Congress.

The Permanent Committee met on April 26, and resolved that the Bureau should consist of one President, five Members, and three Secretaries. These would constitute the executive body. The following were elected:—

President: Mouchez.
Members: Christie, Dunér, Janssen, Struve, Tacchini.
Secretaries: Gill, Loewy, Vogel.

It was decided that their proceedings and any researches instituted by them should be published, and it was intimated by Admiral Mouchez that the Académie des Sciences would generously co-operate with them for that purpose.

Summary.

All the resolutions of the Congress have been passed either unanimously or by very large majorities. They may be briefly summarised:—

I. A photographic chart of the heavens containing all stars down to the 14th magnitude is to be at once undertaken, the plates to be in duplicate.

II. A second series of photographs with shorter exposure, to include stars of the 11th magnitude, is to be made concurrently with the first, for the purpose of forming a catalogue and to determine fundamental positions in the first series.

III. The photographic plates are to be prepared from the same formula.

IV. The photographic telescope is to be identical in all essential particulars with that used by the brothers Henry at the Paris Observatory.

The Government of the French Republic has expressed its intention of taking part in the work, and the necessary instructions have been given to the four Observatories of Paris, Toulouse, Bordeaux, and Algiers, for which photographic telescopes are already being constructed.

Spain, Mexico, Brazil, Chili, and the Argentine Republic have also decided to join in the work at the Observatories of San Fernando, Tacubaya, Rio de Janeiro, Santiago de Chilé, and La Plata; and, according to their representatives' opinion, Austria and Australia will certainly co-operate at the Observatories of Vienna, Sydney, and Melbourne. The Oxford University Observatory has also decided to take part in the work.

The necessary instruments have been ordered for nearly all these observatories.

Spectroscopic Astronomy in 1887.

The O-Gyalla Catalogue.—The second part of the eighth volume of the *O-Gyalla Observations*, which has been recently published, is devoted to a catalogue of the stars of the zone lying between the equator and the fifteenth parallel of south declination, the character of the spectrum of each star being briefly indicated. This catalogue is intended as a continuation of the spectroscopic survey of the northern heavens projected some years ago by Professor H. C. Vogel and Dr. Dunér; and the same classification of stellar spectra has therefore been followed, and the same limit—viz. mag. 7·5—adopted for the faintest stars to be observed. The first instalment of the northern survey appeared in the third volume of the *Potsdam Observations*, and included 4,051 stars, the zone observed lying between Decl. +20° and Decl. −1°. The present catalogue contains 2,022 stars, the great majority being of types I*a* and II*a*. Only three specimens of type III*b* were found, and but one spectrum was suspected of showing bright lines. Four stars, β, δ, ϵ, ζ *Orionis*, are stated to be variable as to their spectra, but the details of the observations are not given.

Identification of Elements in the Solar Atmosphere.—Professor Trowbridge and Messrs. Hutchings and Holden have published during the year, in the *Proceedings of the American Academy of Arts and Sciences* and elsewhere, a series of short papers on the comparison of the spectrum of the Sun with those of various terrestrial elements. The comparisons were made by means of photography, a large concave grating, by Rowland, of more than 20 feet focus, being used to give the spectra. The first spectrum to be compared with that of the Sun was that of air. With the high dispersion employed, the "bright bands" which Dr. H. Draper believed he had detected in the solar spectrum disappeared, or no longer appeared as such, and all apparent connection between them and the lines of oxygen, with which Dr. Draper had identified them, disappeared also. In place of the bright bands numerous dark lines were seen, but neither did these correspond to the oxygen lines, and Professor Trowbridge's conclusion is that, "so far as concerns the spark spectrum in air, and the solar spectrum from λ 3749·8 to λ 5033·85, we can safely affirm that there is no coincidence between them."

With regard to carbon, on the other hand, Professor Trowbridge concludes that there is positive evidence in the solar spectrum that it exists in the Sun. He regards the fluted spectrum of carbon as an example of the reversal of the lines of a vapour in its own vapour, and he states that he has found a remarkable number of coincidences between the dark lines in the solar spectrum on the one hand, and the dark interspaces separating the successive bright lines of the carbon flutings—not

the bright lines themselves—on the other; and he infers that the temperature of the Sun's atmosphere, at the point where carbon is volatilised so as to produce these reversals, approximates to that of the voltaic arc.

With regard to the spectra of metals, Messrs. Hutchings and Holden believe that they have found good reason for regarding as probable the existence of platinum in the solar atmosphere, sixteen coincidences having been detected between λ 4250 and λ 4950. They confirm the presence of bismuth, cadmium, and silver, which other observers have considered probable, but regard the coincidences in the cases of cerium, lead, molybdenum, uranium, and vanadium as insufficient in number and definiteness to establish their presence in the solar atmosphere.

The Spectra of Meteorites.—The department of astronomical spectroscopy in which the most entirely novel results have been obtained during the past year has been that of the study of meteorites. A lengthy and important paper on the results of his examination of meteoritic spectra under various conditions, particularly that of feeble temperature, was read by Mr. Lockyer before the Royal Society on November 17, 1887. His experiments had shown him that it was possible to obtain spectra from meteorites which should reproduce, more or less perfectly, the most peculiar features of almost every variety of spectrum presented to us by the celestial bodies. In the spectra of nebulæ, for instance, seven lines have been detected, of which three were traced to hydrogen, three to low temperature magnesium, and the seventh, which has not yet been traced to its originating element, has been given by the glow from the Dhurmsala meteorite. The most characteristic nebular line was identified with the low temperature fluting of magnesium, and the unusual spectrum obtained from the comets of 1866 and 1867 was ascribed to the same cause. The changes observed in the spectrum of the great comet of 1882 were such as would correspond to the changes induced by change of temperature in the spectrum of a meteorite, and the changes in the spectrum of *Nova Cygni*, and the bright lines in such a star as *R Geminorum* received a similar explanation; whilst a very full, in parts almost a perfect, reproduction of a considerable portion of the solar spectrum has been obtained by taking a composite photograph of the arc spectrum of several stony meteorites, chosen at random, between iron meteoric poles. These and similar observations have led Mr. Lockyer to regard "all self-luminous bodies in the celestial spaces" as "composed of meteorites, or masses of meteoritic vapour produced by heat brought about by condensation of meteor swarms due to gravity," so that "the existing distinction between stars, comets, and nebulæ rests on no physical basis;" all alike are meteoritic in origin, the differences between them depending upon differences in temperature, and in the closeness of the component meteorites to each other. Novæ are explained as produced by the clash of meteor-streams, and most variable

stars are regarded as uncondensed meteor-streams. Stars with spectra like that of *α Orionis* are considered, not as true suns, but as mere "clouds of incandescent stones, . . . probably the first stage of meteoritic condensation," stars with spectra of the first and second types representing the condensed swarm in its hottest stages, whilst spectra of Secchi's fourth type indicate an advanced stage of cooling.

The Spectrum of Hydrogen, Oxygen, and Water-vapour.—Professor Grünwald, of Prague, has propounded a theory, according to which the wave-lengths of the lines due to a certain element in a given compound are to the wave-lengths due to that same element, when the first compound is combined with some further body, as the volume the element occupies in the first case is to the volume it occupies in the second. Examining the low temperature spectrum of hydrogen, he finds that the wave-lengths of its several lines are just double those of the lines of the water spectrum, line for line. Similar but less simple relationships are given for other spectra, and Professor Grünwald concludes from them that hydrogen and oxygen are compound bodies, and are dissociated in the Sun. Hydrogen is inferred to have a composition of the form a_4b; of which the supposed element a is associated with the line of the corona, 1474 K; and b with the "helium" line, D_3.

Determinations of Wave-lengths.—An exceedingly careful determination of the wave-lengths of the D_2 line of sodium has been recently made by Mr. Louis Bell, Fellow of the Johns Hopkins University. The result is to increase by about one-fifth of a tenthmetre Thalén's correction of Ångström's value; the wave-length finally adopted being 5896·08 tenthmetres with a probable error of about 1 part in 250,000. Professor Rowland has followed this by a table of the relative wave-lengths of about 450 standard lines, based upon the above determination of Bell's, and designed for use in connection with his photographic map of the normal spectrum, to determine the error of the latter at any point.

Photographic Study of Stellar Spectra.

The first annual report of the Henry Draper Memorial appeared during the past year under date March 1, 1887, and gave evidence of an employment of photography so skilful and successful as to open up quite a new prospect in the study of stellar spectra. About a year earlier Mrs. Henry Draper had intimated her intention of providing the means for carrying on at the Harvard College Observatory, as a memorial to her late husband, researches similar to those in which he had been engaged during the last years of his life. Professor Pickering undertook the direction of the work, and a threefold programme

was commenced. First, the spectra of all stars of the sixth magnitude and brighter, from the north pole down to south declination 24°, were to be photographed, and a complete catalogue formed from the measurement and reduction of the plates. Secondly, a similar but more extended catalogue was to be prepared, embracing all stars down to the eighth magnitude. And lastly, the spectra of the brighter stars were to be studied in all possible detail.

Up to the date of the report three telescopes had been employed in the work, viz. an 8-inch Voigtländer photographic lens, Dr. Draper's 11-inch photographic refractor, and, more occasionally, the 15-inch refractor of the Harvard College Observatory. The first two had been employed during the first part of every clear night, but Mrs. Draper, seeing how important in themselves and how promising for future achievements were the results obtained, has proposed to devote two additional telescopes —reflectors of fifteen and twenty-eight inches aperture respectively—to the work, and to provide means for at least three of the telescopes being kept in constant use during the whole of every clear night. And not only has observation thus been arranged for; Mrs. Draper likewise has taken care that the photographs should be measured and reduced, a considerable force of computers being employed for the purpose, and the publication of the results in a suitable form has been provided for.

The spectra obtained so far have been produced by reverting to Fraunhofer's method and placing a large prism before the object-glass. Four large prisms of 15° were produced by splitting a thick plate of glass diagonally. In forming the two catalogues the Voigtländer lens of eight inches aperture has been used, and the spectra of all the stars over a region 10° square were obtained at once upon a single plate. As formed on the plate the spectra were of course but mere lines, but by adjusting the prism with its edge parallel to the equator, and by giving a motion to the driving clock somewhat different from that necessary to make the telescope follow a star precisely, any desired breadth might be given to the spectra. For equatorial stars the exposure for the first catalogue, that of stars down to the sixth magnitude, lasted for five minutes, and the average breadth of the spectrum was 1^{mm}. For the catalogue of fainter stars an exposure of an hour was given. The length of the spectrum was about 12^{mm} for the brighter and 6^{mm} for the fainter stars, the distance between the H and K lines being about one-third of a millimetre. At the date of the report the first cycle, covering the entire sky from zero to twenty-four hours of right ascension, had already been completed and sixty-four plates had been taken in the second cycle. In all, photographs of 15,729 stellar spectra had been obtained, identified, and measured, in the space of a few months. Such an achievement affords a most striking illustration of the potency of the weapon for research which dry-plate photography has placed in our hands. To have secured the

same result by means of direct observation would have required the united efforts of several observers for a succession of years, whilst the fainter spectra would for an equal aperture have been beyond the grasp of the keenest eye to study in detail.

But it is the results obtained under the third head of the programme—the detailed study of bright spectra—which have excited the greatest wonder and admiration. For these the 11-inch refractor has been employed, and one, two, three, or even four prisms have been used before the object-glass. A beautiful spectrum of *Pollux*, for instance, was obtained with the full dispersion in fifty minutes. The distance between H and K on this plate was about four-and-a-half millimetres, and the lines were shown with great distinctness, so that the spectrum easily bore enlarging five times as regards its length, and therefore as regards its dispersion. By the use of a cylindrical lens close to the enlarging lens the breadth of the spectrum was not only increased to four inches, but a number of defects, similar in appearance to the "dust lines" in an ordinary spectroscope, were removed. The specimens of stellar spectra enlarged in this manner which have been prepared by Professor Pickering, and some of which he has presented to this Society, are shown on a scale but one-third less than those used by Ångström and Cornu in the construction of their charts, and the lines are rendered with a clearness and definiteness which would be creditable in a photograph of the solar spectrum. Such results will render it possible to discuss the details of stellar spectra with a minuteness which but a little while ago could scarcely have been hoped for. Amongst some of the more interesting details already brought out may be mentioned the discovery of a series of bright lines in the spectra of the interesting long period variables *Mira Ceti* and *T Orionis*, which appear to correspond to the two violet lines of hydrogen and to four of the dark lines discovered by Dr. Huggins in his photographs of spectra of the *Vega* type. H and K were, however, shown as dark lines in these two stars.

The programme for the future, as laid down in the report, embraced the study of the fainter spectra, particularly those showing shaded bands or bright lines, and those of variable stars, by means of a spectroscope, in which a concave lens replaces the slit and collimator, used in conjunction with the 28-inch reflector. The spectra of the brighter stars were to be classified, and the wave-lengths of their lines determined; comparisons were to be made with terrestrial spectra, and the displacements of the stellar lines due to motion in the line of sight determined. And it is hoped that the work may not have to be confined to the northern hemisphere, but that, by the establishment of a station to the south of the equator, it may be extended to every part of the heavens.

Schiaparelli's Observations of Mars in 1882.

After a long delay the detailed account of Professor Schiaparelli's observations of *Mars* during the opposition 1881–82 has appeared in the *Atti della Reale Academia dei Lincei.* A preliminary notice appeared in 1882 in the *Transunti* of the same Academy, and created considerable sensation by the announcement of the duplication of many of the so-called canals. The present memoir is drawn up and arranged exactly like the two previous ones on the observations made in 1877 and 1879. The measures of the position-angle of the northern polar spot made in 1882 furnish a result for the position of the north pole of *Mars* in space which agrees very closely with the results from the two previous oppositions. Next follow the descriptions of the various surface markings as seen in 1882, the resulting map being given as formerly on Mercator's projection. In general the more prominent markings on the map agree with those on the map of 1879, the most notable difference being the region about the northern end of the *Syrtis Major* (*Kaiser Sea*), where a new dark band, concave towards the south, appeared north-west of *Nilus*, while the *Coloe Palus*, north-east of the *Syrtis*, was not seen. This region has also by other observers been seen to undergo temporary changes or obscurations—*e.g.* by M. Perrotin in 1886 (*Bull. Astron.* July 1886).

The principal interest attached to the memoir is the full account it gives of the remarkable duplication of many of the canals in 1881–82, which on its first announcement was received with much scepticism. Thirty duplications took place between 1881, December 19, and 1882, February 22, of which nineteen were cases of a well-traced and parallel line being formed at a distance of from 4° to 10° or 12° from a previously existing canal, while the remaining were less certainly established or were cases where the lines were not quite parallel. After describing in detail the principal cases the author remarks that the phenomenon seems to be of a periodic character. In 1877 no traces of duplication were seen during the weeks which preceded or followed the southern solstice of *Mars*, which occurred twenty-one days after the opposition. A single case was seen in 1879 on December 26, shortly before the vernal equinox of the northern hemisphere (January 21, 1880), when the *Nilus* appeared double. The very same phenomenon occurred o January 11, 1882 (this time five weeks after the vernal equinox), and remained visible until the end of February, while, as already mentioned, several other duplications had already taken place during the latter half of December. At the opposition of 1884 Professor Schiaparelli observed similar duplications in January, February, and March, the vernal equinox having occurred on October 26, 1883, while the next northern solstice fell on May 13, 1884. Finally in 1886 the greater part of the duplicate

canals had disappeared, and only one long one was seen at Milan and at Nice, while some others were traced with more or less certainty. The northern solstice fell on March 30. Prof. Schiaparelli therefore concludes that the phenomenon of duplication is connected with a period corresponding to the tropical year of *Mars* and depending on the seasons; that it commences to show itself about the vernal equinox, the greater number of cases appearing in the second month after this equinox; and that it disappears again gradually until hardly any remain near the time of the northern solstice. It is as yet impossible to say whether anything similar takes place during the autumn of the northern hemisphere. It is pointed out that a tendency to duplication is also shown in other and better-known features of *Mars*, such as the *Mare Cimmerium* (the eastern half of *Maraldi Sea*) and the *Sinus Sabæus* (*Herschel II Strait*), and the circumstance that these phenomena were in 1886 confirmed by other observers (at Milan by Celoria, and at Nice with a 15-inch refractor by Messrs. Perrotin, Trépied, and Thollon) is referred to as making it impossible to deny their reality, however difficult they may be to explain. J. L. E. D.

The Liverpool Astronomical Society.

This Society, which came into existence only a few years ago by the union of some ten amateur observers, determined to foster a liking for astronomy, especially among the possessors of small telescopes, has been so eminently successful that it now numbers nearly 600 members, and has just published the fifth volume of its transactions.

To promote systematic work in different branches of astronomy, sections have been formed, each under a responsible head, for the separate study of the Sun, Moon, planets, double stars, &c. By this means important observations are brought together and published, which might otherwise remain lost in the note-books of the observers.

The volume under consideration, as well as those that precede it, contains a large amount of valuable observations, which form a measure of the useful work the Society is accomplishing. A series of papers by Mr. Elger, on "The Moon Surveyed in Common Telescopes," illustrated with sketches of portions of the lunar surface, is an interesting contribution to the subject, and numerous papers on Planets, Meteors, Double Stars, and other branches of observational astronomy indicate the activity with which the Society is pursuing its excellent object.

The Almucantar.

Vol. xvii. of the *Annals of Harvard College Observatory* consists of an account of Mr. S. C. Chandler's new instrument,

the "almucantar," and of its use during a year in observation. In the shape described the almucantar is a zenith telescope of 3·97 inches aperture and 43·8 inches focal length. It differs from the usual form in that instead of being watched by spirit levels, which serve to determine the departure of its axis from its intended direction, the telescope is supported by a float resting in a mercury trough, which in turn is supported on the approximately vertical pillar. Thus when clamped in altitude the line of collimation describes a true small circle of altitude, subject only to a very small correction which might for practical purposes be almost neglected.

The telescope is furnished with a system of cross lines ruled on glass and placed in the focus; in order that a suitably high power may be used these are necessarily very close, and as the mode of observation is entirely by transit over the wires (and mainly over the horizontal ones), a chronograph becomes a necessity. The author of the volume, who is also the inventor of the instrument, gives full details of the adjustments and of the theory of the instrument, so that anyone who may desire to use it will have the means of entering on its study with a safe guide to success. The reductions of a portion of the observations are ample as types, while the results serve as a measure of its value.

There can be no doubt that when the necessary skill has been acquired the instrument is capable of giving results of a very high order of accuracy. Mr. Chandler has applied it to the determination of latitude and time from assumed places of stars, and then investigates the places of a number of stars contained in Auwers's Fundamental Catalogue. The advantage of the instrument for such a purpose is that the results are entirely free from all error arising from flexure, defects of pivots, errors of micrometer screws, &c., and those arising from refraction are practically eliminated. Thus the errors are of a different nature from those of the meridian instruments in ordinary use, and it appears suitable for affording a check on their results. In fact, Mr. Chandler has deduced from his observations what become corrections to Auwers's Catalogue, and in Right Ascension he shows that the almucantar gives in a great majority of cases, when the corrections are at all sensible, similar results to those from recent Greenwich work. It may be doubted whether this instrument, involving as it does the disuse of the micrometer, and requiring to be allowed to settle after setting to the computed place of an object, will be as convenient for geographical work as the older form of the zenith telescope; but, especially in the improved form proposed at the end of the volume, it seems likely that it will be used to check the results of meridian observations of stars, and lead to a more satisfactory knowledge of systematic errors of catalogues.

There is much interesting discussion of practical questions which will repay the reader, but which it would require too much space to describe adequately.

Papers read before the Society from February 1887 *to February* 1888.

1887.

Mar. 11. A proposed nomenclature for star colours. W. S. Franks.

Observations of the variable star S (10) *Sagittæ*. J. E. Gore.

Observations of Comets made at the Royal Observatory, Cape of Good Hope, in the year 1886. Communicated by D. Gill.

Photographic search for the minor planet *Sappho* 80. I. Roberts.

A working catalogue of "red" stars. G. F. Chambers.

Notes on reflecting telescopes. Lieut.-Gen. J. F. Tennant.

The occultation of *Aldebaran*, 1887, March 2. C. L. Prince.

Elements of Comet 1886 *e* (Finlay). W. H. Finlay.

Comet 1887 *a*. W. H. Finlay.

On the images formed by reflecting mirrors and their aberration. Lord McLaren.

Second occultation of *Aldebaran*, 1887. Rev. S. J. Johnson.

Note on the near approach of the Moon to *α Tauri*. T. G. E. Elger.

Observations of Winnecke's Comet, 1886, made at Windsor, New South Wales. J. Tebbutt.

The Moon and *Aldebaran*, 1887, March 2, as seen at the Radcliffe Observatory, Oxford. E. J. Stone.

Description of a new measuring rod. E. Crossley.

A centring tube for reflecting telescopes. E. Crossley.

Observations of Comets, *e* 1886 (Finlay), *b* 1887 (Brooks), *c* 1887 (Barnard), and *d* 1887 (Barnard), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the atmospheric transmission of visual and photographically actinic light. Capt. W. de W. Abney.

Observations of Comet 1887 *a*, made at the Adelaide Observatory (extract from letters to the Astronomer Royal). C. Todd.

April 6. On the choice of instruments for stellar photography. H. Grubb.

On the orbit of OΣ 400. J. E. Gore.

Lunar occultations on March 29, 1887. C. L. Prince.

On the formulæ for computing the apparent positions of a satellite, and for correcting the assumed elements of its orbit. A. Marth.

Remarks on some of the present aspects of celestial photography. Prof. C. Pritchard.

Observations of Comet *b* 1887 (Brooks), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the variations of level and azimuth of the Transit Circle of the Royal Observatory, Greenwich. H. H. Turner.

May 13. Occultation of *a Tauri*, 1887, March 2. Lieut.-Col. G. L. Tupman.

The sidereal system, revised in 1887. Maxwell Hall.

Observations of *Saturn* and δ *Geminorum*, January—February, 1887. J. Tebbutt.

On the probable errors of transit observing. W. H. Finlay.

Sextant observations of Comet *a*, 1887. Capt. E. J. Molony.

The orbits of Comets Fabry and Barnard-Hartwig. Dr. J. Morrison.

Ephemerides of the satellites of *Mars* during the oppositions of 1888 and 1890. Dr. J. Morrison.

On the inclinations of cometary orbits. W. H. S. Monck.

Notes on a MS. eclipse volume. Rev. S. J. Johnson.

Memoir on *Jupiter*. N. E. Green.

On some nebulæ hitherto suspected of variability or proper motion. J. L. E. Dreyer.

Note on the effect of refraction in stellar photography. J. L. E. Dreyer.

On Prof. G. W. Hill's paper on Delaunay's method. E. Neison.

On the orbit of Comet II., 1883. R. Bryant.

On the formulæ for correcting approximate elements of the orbits of binary stars. A. Marth.

The right ascensions of certain stars within ten degrees of the pole, reduced from observations by F. G. W. Struve. H. Lefavour. Communicated by Prof. Safford.

June 10. Observations of the companion of *Sirius* made at the Dearborn Observatory, Chicago. Prof. G. W. Hough.

A catalogue of 480 stars to be used as fundamental stars for observations of zones between 20° and 80° south declination. Prof. A. Auwers.

On the orbit of Σ 1757. J. E. Gore.

Physical observations of *Saturn* in 1887. T. G. E. Elger.

Measures of southern double stars made at the Observatory, Sydney, New South Wales. Communicated by H. C. Russell.

A new general catalogue of nebulæ and clusters of stars, being the catalogue of the late Sir J. F. W. Herschel, revised, corrected, and enlarged. J. L. E. Dreyer.

On the parallax of 61_1 and 61_2 *Cygni*, as obtained by the aid of photography. Prof. C. Pritchard.

The Solar Corona, as shown in photographs taken during total eclipses. W. H. Wesley.

On an old engraving of *Jupiter*. Capt. W. Noble.

Observations of Nova *Cygni*, of some of the planets, and of Comet Barnard, made at Mr. Wigglesworth's Observatory with the 15·5-in. Cooke equatoreal. J. G. Lohse.

Note on the performance of the Westminster clock. T. Buckney.

A comparison of the star places of the Argentine General Catalogue for 1875 with those of the Cape Catalogue for 1880, and with those of other Southern Star Catalogues. A. M. W. Downing.

On a corrector for adapting an ordinary object-glass to photography. W. H. M. Christie.

Nov. 11. Observations of the planet *Sappho* made at the Cambridge Observatory with the Northumberland equatoreal and square-bar micrometer. Communicated by Prof. J. C. Adams.

On the orbit of Comet II., 1883. Lieut.-Gen. J. F. Tennant.

Note on the latitude and longitude of the Maresfield Observatory. Capt. W. Noble.

Ephemerides of the satellites of *Saturn*, 1887–88. A. Marth.

Observations of comets and of *Sappho* (80) at Harrow. Lieut.-Col. G. L. Tupman.

Ephemeris of the satellites of *Neptune*, 1887–88. A. Marth.

On the orbit of *p Eridani*. J. E. Gore.

Occultation of *Regulus* by the Moon observed at the Dunsink Observatory. Communicated by Sir R. S. Ball.

Occultation of *Regulus*. Rev. S. J. Johnson.

Observations of comets made at the Orwell Park Observatory in the years 1886–87. J. I. Plummer.

On the appearances presented by the satellites of *Jupiter* during transit, with a photometric estimation of their relative albedos, and of the amount of light reflected from different portions of an unpolished sphere. E. J. Spitta.

On photographs of the nebulæ 57 M *Lyræ*, 27 M *Vulpeculæ*, the cluster 13 M *Herculis*, and of stars in *Cygnus*. I. Roberts.

The total solar eclipse of August 19, 1887. Rev. S. J. Perry.

Note on the probable errors of the star places of the Argentine General Catalogue for 1875, and the Cape Catalogue for 1880. A. M. W. Downing.

On the reduction of star places by Bohnenberger's method. Prof. T. H. Safford.

Ephemeris for physical observations of *Jupiter*, 1888. A. Marth.

The total solar eclipse of 1887, August 19. Dr. R. Copeland.

Further researches on stellar parallax by the photographic method. Prof. C. Pritchard.

Results obtained with the personal equation machine at the Royal Observatory, Greenwich. H. H. Turner.

Catalogue of the mean colours of 758 stars, and appendix, containing the colours of 26 southern stars. W. S. Franks.

Dec. 9. Description of the personal equation machine of the Royal Observatory, Greenwich. W. H. M. Christie.

On the double star Σ 1847. J. E. Gore.

Ephemeris for physical observations of *Mars*, 1888. A. Marth.

1888.

Jan. 13. The chief meteor showers. W. F. Denning

Heights of fireballs and shooting stars. W. F. Denning.

Nebula in *Andromeda*, and *Nova* 1885. T. W. Backhouse.

Notes on the solar surface of 1887. Rev. S. J. Perry.

Observations of the phenomena of *Jupiter's* satellites made at Windsor, New South Wales, in the year 1887. J. Tebbutt.

Ephemeris of the satellites of *Mars*, 1888. A. Marth.

On the cross reticule. Lieut.-Col. G. L. Tupman.

The opposition of *Sappho* in 1888. R. Bryant.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1887, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on the definition of reflecting telescopes, and on the images of bright stars on photographic plates. Lieut.-Gen. J. F. Tennant.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1878, No. XI. Communicated by the Astronomer Royal.

Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, during the year 1887. Communicated by the Astronomer Royal.

Note on testing polished flat surfaces. A. A. Common.

Note on the total solar eclipse of 1889, January 1. J. R. Hind.

List of Public Institutions, and of Persons who have contributed to the Library, &c., since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
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British Horological Institute.
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Batavia Observatory.
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Berlin, Physical Society.
Berlin, Royal Academy of Sciences.
Berlin, Royal Observatory.
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Bombay Branch of the Royal Asiatic Society.
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Boston Scientific Society.
Brisbane, Queensland Branch of the Geographical Society of Australasia.
Brussels, Royal Academy of Sciences.
Buda-Pesth, Hungarian Academy of Sciences.
Calcutta, Asiatic Society of Bengal.
Cape of Good Hope, Royal Observatory.
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Christiania, Norwegian Meteorological Institute.
Coimbra Observatory.
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Copenhagen, Royal Academy of Sciences.
Cordoba, Argentine National Observatory.
Delft, Polytechnic School.
Dijon, Academy of Sciences.
Glasgow (Missouri), Morrison Observatory.
Göttingen, Royal Society of Sciences.
Haarlem, Teyler Museum.
Harvard College Astronomical Observatory.
Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
Kalocsa, Haynald Observatory.
Karlsruhe Observatory.
Königsberg, Royal University Observatory.
Leipzig, Astronomical Society.
Leipzig, Royal Society of Sciences of Saxony.
Lisbon, Royal Academy of Sciences.
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Madrid, Royal Academy of Sciences.
Marseilles, Flammarion Scientific Society.

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Melbourne, Royal Society of Victoria.
Mexico, Scientific Society.
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Montreal, Geological and Natural History Survey of Canada.
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Rome, Royal Academy *dei Lincei.*
St. Petersburg, Imperial Academy of Sciences.
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Sydney, Royal Society of New South Wales.
Tacubaya Observatory, Mexico.
Tasmania, Royal Society.
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Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
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Vienna, Imperial Observatory.
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Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
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Washington, United States Naval Observatory.
Yale College Observatory.
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Zurich, Society of Natural History.
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Editors of the "American Journal of Science."
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Editor of the "Astronomische Nachrichten."
Editor of the "Athenæum."
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ADDRESS

Delivered by the President, Dr. J. W. L. Glaisher, on presenting the Gold Medal of the Society to Dr. Arthur Auwers.

The Council have awarded the Gold Medal of the Society to Dr. Arthur Auwers, of Berlin, for his new reduction of Bradley's observations; and I now have the pleasure of laying before you the considerations which have influenced the Council in desiring, at the present time, to recognise to the full extent of their power, by this public mark of their highest appreciation, the value and importance of the service that Dr. Auwers has thus rendered to astronomy.

If we except the great name of Newton, there is no English astronomer whose discoveries can be compared in importance to those of Bradley. The rare combination of observational skill with patience and genius displayed in his investigation of the laws which regulated the small variations which he had detected in the places of the stars, and his brilliant and successful explanation of the causes that produced them, have often been the theme of admiration. But for this happy union of the persevering skill of the observer with the penetration and learning of the philosopher, it could not have happened in the history of our science that it should have fallen to the lot of the same man to disentangle from these small discrepancies two distinct classes of delicate and beautiful phenomena, and, by means of a sustained investigation, extending over more than twenty years, not only to assign to each its true physical cause, but to found his explanations upon a basis which should render them absolutely irrefragable. Bradley's discoveries were the just reward of a splendid application of the best and highest qualities of the scientific investigator, and the record of his brilliant achievements forms one of the wonders of astronomy and the glories of his country.

It was after his discovery of aberration, and while he was still engaged upon the discrepancies which were to lead him to the discovery of nutation, that he was appointed the successor of Halley at the Greenwich Observatory; and it was in that position that he was destined to confer upon observational astronomy a direct benefit only secondary in importance to his own great advances in the theory of the science. Bradley's meridian work

holds a unique position in the history of practical astronomy. His observations are the first which in point of regularity and accuracy are comparable to those of modern times, and they stand at the head of the long and famous series of meridian observations upon which the widespread reputation of the Greenwich Observatory mainly rests. Thus they are not only of the highest practical importance as affording material of unique value for the improvement of the solar, lunar, and planetary tables, and the determination of proper motions, but they claim attention from the historical point of view as the actual commencement of the vast groundwork of meridian observations with which the assiduous industry of the great observatories of the world has now enriched astronomy.

In 1727 Bradley erected at Wanstead his famous zenith sector, and two years later his memoir, containing the discovery of aberration, was published in the *Philosophical Transactions*. In 1742 he was appointed to the Greenwich Observatory, and in 1748 he published his discovery of nutation.

When Bradley came to Greenwich his first care was to repair Halley's instruments, viz. the transit and the eight-foot iron quadrant by Graham. Halley, who was without any assistance, had confined himself to observing with the quadrant since its erection in 1725; but Bradley, who succeeded in obtaining from the Government the services of a regular assistant, determined to employ simultaneously both the transit and the quadrant in his observations.

In 1749 he made application to the Government for improved instruments, with the result that he was provided with a transit instrument eight feet long and a brass quadrant of eight feet radius, both made by Bird. The celebrated zenith sector with which he had discovered aberration and nutation was also transferred from Wanstead to Greenwich, and added to the equipment of the observatory, a new apparatus for its suspension being provided. This instrument was used not only for obtaining the zenith distances of stars which passed the meridian within $6\frac{1}{4}°$ of the pole, but also as a means of determining with precision the collimation errors of the two mural quadrants—the old iron one by Graham, and the new brass one by Bird. The new instruments were erected in 1750.

At first Bradley turned the new quadrant towards the north, and employed it in observing circumpolar stars with the view of determining the latitude, which was not better known than in Flamsteed's time, as the iron quadrant had been kept continually directed to the south; but in 1753 he fixed it in its permanent position towards the south, placing the iron quadrant towards the north. From the erection of the new instruments in 1750 until Bradley's death in 1762 they were regularly used by Bradley and his assistant in making systematic observations of the stars, Sun, Moon, and planets. After Bradley's death the observations passed into the hands of his executors, and were finally presented

to the University of Oxford. They were published by the University in two folio volumes, the first of which, edited by Dr. Hornsby, appeared in 1798, and the second, edited by Dr. Robertson, in 1805. It was therefore not until forty-three years after Bradley's death that the memorable series of observations made by him with Bird's excellent instruments were first given to the world.

The observations as published were unreduced. In 1807 Olbers communicated his copy to Bessel, who undertook the reduction of the whole of the observations of the stars. The results were published in 1819 in Bessel's *Fundamenta Astronomiæ*. It would be indeed superfluous, and even out of place, to attempt to give in this room any panegyric upon this classic volume, so widely known and justly valued as one of the landmarks of our science. I will only say that one feels almost reconciled to the fact that Bradley's labours should have remained unproductive for the long period of more than half a century by the knowledge that all this time they were merely waiting for so great and so worthy an interpreter. 'Vir incomparabilis' is Bessel's description of Bradley upon the title-page. These words may be applied with equal truth to Bessel himself. Each in his age holds a similar rank among his contemporaries, and Bradley's work could not have been placed in the hands of one more thoroughly in sympathy with the spirit of his life or more competent to derive from his observations the fundamental astronomical facts and laws which they implicitly contained. There are greater names in astronomy, but there are but few astronomers who have devoted their lives and talents more successfully and indefatigably to unravelling the practical mechanism of the heavens and placing the science upon a sound and exact basis than James Bradley and Frederick William Bessel.

It is no disparagement to the excellence of Bessel's reductions and theoretical conclusions that the rapid advance of astronomy in the next half-century should have rendered it possible to extract from Bradley's noble work results of even greater value than it was in Bessel's power to reach. And not only has the progress of astronomy improved every process and greatly increased the accuracy of the value assigned to every constant and coefficient, so that the reduction of the observations could be effected with a degree of exactitude quite impossible in Bessel's time, but it has also had the effect of conferring upon the results derived from the observations an even greater astronomical importance; so that a new necessity had arisen for effecting the reduction with the highest possible degree of precision. In fact, it is to the same causes that we owe both the means and the occasion of undertaking a new reduction; for so great has been the astronomical activity of our century that in almost every branch of the science a degree of accuracy has been attained which has made it more than ever desirable that no effort should be spared to

extract from these early observations all the information that they are capable of yielding.

The new reduction has been effected by Dr. Auwers, and the same good fortune that gave to Bradley's observations their first interpreter has attended them also in their second. There is no living astronomer who occupies a higher position among his contemporaries than Dr. Auwers, and in the particular department of the reduction and discussion of observations he stands without a rival. I believe that the new reduction of Bradley's observations is in every respect worthy of his high reputation, and that it leaves nothing to be desired either as regards method of treatment or perfection of execution.

I am in hopes that the points connected with this new reduction which I am enabled to lay before the Society will afford some idea of the nature of the work undertaken and the elaborate care and skill with which it has been carried through to a successful completion. Before giving an account of the great work itself it will be convenient, however, to mention in detail the special reasons which had rendered a new reduction so very desirable in the general interests of astronomy.

Le Verrier's calculation of the right ascensions of the fundamental stars showed unexpectedly large deviations from Bessel's determinations in the case of a considerable number of these stars, and threw doubt both on the value of the observations as a means of determining proper motions and upon the accuracy of their reduction. An investigation of the errors of the transit instrument made in 1855 by Peters showed deviations from Bessel's assumptions, which might have the effect of introducing considerable corrections in the reduction of stars near the pole. In the reduction of the quadrant observations, which were not recalculated by Le Verrier, it had been known for some time that there must exist serious imperfections, both on account of the unsatisfactory determination of the index errors and owing to the fact that Bessel was necessarily compelled to deduce from the observations themselves both the latitude and the refractions. The value assigned to the former differed considerably from that obtained by more recent determinations. It was therefore to be feared that the calculated declinations might be affected by systematic errors of the same order. Several corrections, also, such as in the great majority of stars the solar nutation, had been neglected, and erroneous values of the constants required in the deduction of the mean places had been applied. For example, the adopted value of the constant of nutation was $0''{\cdot}4$ too large, which alone would produce an appreciable systematic error in the proper motions derived from the observations. Finally, Bessel's reduction was incomplete, for, except in the case of a few bright stars, he employed only five observations, although in very many cases the number of observations was much greater. For these reasons, considering the unique position in which Bradley's

observations stand, it was clear that the time had come when a new reduction should be undertaken, and it was obviously of the highest importance that it should be carried out with the greatest possible completeness and with all the perfection that modern methods of reduction could afford. This was the great work that Dr. Auwers commenced in 1866 and completed in 1876.

In these ten years he has effected an entirely new reduction of all the observations of the stars and of the Sun made with the transit instrument, the brass quadrant, and the zenith sector from their erection at Greenwich in 1750 till Bradley's death in 1762. He also, in order to obtain the means of determining the index errors of the quadrant, has reduced the observations made with the zenith sector at Wanstead in 1727–1729 and at Greenwich in 1768–1786. Since the completion of this work Dr. Auwers has also, at Professor Newcomb's request, carried out a new reduction of the observations of the planets made between 1750 and 1762.

The reduction has been founded not upon the printed volumes of observations but upon a manuscript copy of Bradley's original journal, which is now preserved in the library of the Greenwich Observatory.* The copy was very carefully compared with the original. A transcript was also made of all the other papers of Bradley's that related to the meridian observations. From these papers many valuable explanations were obtained.

In the course of the reduction a very great number of errors were brought to light. These were mostly detected by the want of agreement between the observations themselves, and could almost always be corrected by means of a careful examination. Bessel had already given an extensive table of corrections to Bradley's observations, which occupies sixteen folio columns in the Introduction to Mayer's observations; but Dr. Auwers has added no less than thirty-four columns of additional errors.† Some of these occur in observations which were not made use of by Bessel; the majority, however, escaped his notice in consequence of his method of employing means instead of single observations.

In proceeding now to give an account of Dr. Auwers' work I will first briefly describe the catalogue, which forms of course the principal result of the new reduction, and then pass on immediately to the explanation of the manner in which the reduction was carried out.

The new catalogue contains 3,268 stars. These comprise the 3,222 stars included in the *Fundamenta* and other stars which Bessel had overlooked or had decided not to reduce, besides some which were only observed with the zenith sector. The

* Bradley's original manuscripts were transferred from Oxford to Greenwich in 1861.

† Dr. Auwers found that the first volume of the printed observations (by Dr. Hornsby) had been very carefully prepared for the press, but that this was not the case with the second volume.

number of stars completely observed by Bessel amounts to 2,702: in addition to these there are 290 which were observed only in right ascension and 274 which were observed only in declination, besides two stars which have accidentally crept into the catalogue of the *Fundamenta*, though they were not observed by Bradley. These two stars have been retained in order to avoid any alteration in the numbering. The epoch of this catalogue, which is the same as that of the *Fundamenta*, is 1755.

A second catalogue of these 3,268 stars has also been made for the epoch 1865. This was founded principally upon the Greenwich observations 1854–1867 (the two seven-year catalogues), but some special observations have been made both at Greenwich and Berlin in order to render it as complete as possible. It contains only ten stars, whose places had to be derived from the older determinations: one of these was accidentally overlooked; the other nine are very southern stars.

The proper motions have been determined by comparison of the two catalogues. For this purpose the precessions were calculated for the three epochs 1755, 1810, and 1865, and by a rigorous mathematical calculation Bradley's positions were carried on from 1755 to 1865. As the differences are on the average divided by 110 (very rarely by less than 100 and frequently by more than 120), and as the two catalogues are derived from observations made at the same place and calculated with the same refractions, there is every reason to hope that the resulting proper motions possess considerable accuracy and are as free as possible from systematic error.

In the case of the co-ordinates which remained undetermined by Bradley, use has been made of the oldest available determinations, chiefly by Piazzi or Groombridge, which were compared with the 1865 catalogue. Their values were then carried back to 1755 in order to fill up the gaps in the catalogue.

In describing the actual methods and the special results of the new reduction, it is convenient to consider separately (1) the right ascensions; (2) the zenith distances; (3) the determination of the equinox and latitude.

The right ascensions were reduced in the following manner:—

The errors of level, azimuth, and collimation were taken from the late Professor Peters's memoir, published in the *Naturforschende Gesellschaft* of Danzig for 1855, except in the case of a few long periods which it seemed desirable to divide into several shorter intervals. When the transit observations were thus corrected, the differences between the right ascensions of the fundamental stars were computed, the observations being compared with ephemerides calculated for the years 1750–1762 by means of the new elements of the *Fundamenta* and the constants of reduction now in use. The first step was to calculate the differences between the individual stars, which were separated into two groups, *a* and *b*, the group *a* comprising α, γ, and β *Aquilæ*, and the group *b* com-

prising *α* and *β Geminorum* and *Procyon*. Next the three stars *Arcturus*, *α Lyræ*, and *α Cygni* were compared with the mean of group *a* (forming together with that group the extended group A) and the seven stars *Aldebaran*, *β Tauri*, *Capella*, *β* and *α Orionis*, *Sirius*, and *α Leonis* were compared with the mean of group *b* (forming with it the extended group B). Thirdly, all the observations relating to group A were reduced to *α Aquilæ*, and all the observations relating to group B were reduced to *Procyon*.

By means of the differences obtained by these investigations the difference of right ascension between *α Aquilæ* and *Procyon* was obtained, this determination being derived from all available comparisons of observations relating to one group with the mean of observations relating to the other group at the culminations next preceding and following. Monthly means of the differences were formed, and the universal yearly mean was derived from them, the daily period in the errors of level and azimuth, and in the rate of the clock, being eliminated.

Thus the right ascensions of the sixteen stars became known, assuming for *α Aquilæ* the right ascension of the *Fundamenta*. But as Bessel compared all of these stars, except *β Tauri*, separately with the Sun, a common correction was applied to their right ascensions so as to reduce to zero the mean of their deviations from the *Fundamenta*.

The right ascensions of the remaining twenty of Maskelyne's thirty-six fundamental stars were determined by comparing their observations, which were much less in number, with the places of such of the preceding sixteen stars as happened to be observed with them.

In this manner the complete catalogue of the thirty-six fundamental stars was constructed. This catalogue, which was definitive as regards the differences, but provisionally referred to the equinox of the *Fundamenta*, was then used to derive the apparent right ascensions of the other stars. These were reduced to 1755·0, the tables for A, B, C, D being computed with Professor Peters's coefficients, and the values of *a*, *b*, *c*, *d* being computed for 1755 with the positions of the *Fundamenta*. For stars between 60° of declination and the Pole, however, the latter values were calculated for 1750 and 1760, and deduced by interpolation for the dates of the observations. It is in this state of reduction that the right ascensions appear in vol. ii. of Dr. Auwers's work.

The new reduction is superior to the old in the following respects:—

(1) The instrumental errors have been more accurately determined and applied with much greater thoroughness. With respect to these errors Bessel distinguished 63 periods: in the new reduction there are 160. In 27 of Bessel's periods, embracing altogether an interval of 6½ years, or more than half of the whole period under consideration, the errors were assumed to be zero in the old reduction; in many of these periods, however, the errors are found to have been considerable.

(2) The clock errors have been more accurately determined by means of the 36 stars than by the 14 used by Bessel.

(3) The personal equations between Bradley and his assistants in observing the transits have been taken into account. For this purpose the manuscript copy was essential, as in the printed volumes the different observers are not distinguished, the existence of personal equation having been at that time unknown. In the case of Bradley and his assistants the equations are found to have amounted to $0^s{\cdot}24$, so that the daily clock rates obtained without reference to personal equation may be in error by as much as $0^s{\cdot}5$. It frequently happened that all the clock stars were observed by Bradley, and a long series of catalogue stars by the assistant, or *vice versâ*, so that on all these days the right ascensions had to be cleared from the whole amount of the personal equation.

(4) The reduction from the observed places to the mean places has been effected in a more rigorous manner. As each single observation has been separately reduced to 1755·0, it was possible to detect and correct the large number of errors in the observations which have been already referred to.

The success of these improvements in the methods of reduction is shown by the greatly increased agreement between the single observations of the same stars. If we restrict ourselves to those errors the amount of which can be inferred from the differences between repeated observations, four observations of right ascension in the new reduction are equivalent in weight to seven observations in the old reduction.

(5) The accuracy has also been increased by the use of all the observations. Bessel, as has already been mentioned, only used five for a large proportion of the catalogue stars. The weight of the right ascensions given in the catalogue, as measured by probable error, is on the whole more than double the weight of those given by Bessel.

(6) Even more important, however, than this increase in the accuracy of the single positions is the fact that the more complete discussion of the observations of the *Fundamenta* stars has shown the existence of very considerable systematic errors in Bessel's right ascensions. Besides the correction of the equinox, which will be referred to further on, the right ascensions of the *Fundamenta* were found to require the following corrections :—

R.A. h	Corr. ″	R.A. h	Corr. ″
0	−0·8	14	1·0
2	−0·5	16	0·7
4	+0·1	18	0·2
6	+0·6	20	−0·4
8	−0·6	22	−0·6
10*	−0·5	4	−0·8
	+0·6		

* For 9^h the correction is $-0''{\cdot}$.

The corrections required for the single right ascensions as given in the catalogue of the *Fundamenta* amount to more than $3''$ sec. δ (including the above systematic corrections) in about 200 instances.

I now come to the mode of reduction of the quadrant observations.

There were two different systems of graduation upon the limb of the quadrant. By the inner arc the quadrant was divided to every $5'$: these intervals were subdivided by the vernier to every $30''$, and these again by the micrometer screw to every second. By the outer arc the quadrant was divided into ninety-six parts: these were subdivided by the vernier into sixteen smaller parts, each of which was therefore equal to $13''{\cdot}2$; and these were again divided by the micrometer screw to every second.

In the reduction of the individual observations the readings of the outer divisions were alone used, as it appeared that these divisions were the more reliable as regards the single graduations. The length of the arc of the quadrant was assumed to have been exactly 90° at all temperatures. It was found by experiments made by Bradley, and by the comparison of large differences of zenith distances observed at different temperatures, that no sensible deviation from this assumption could be detected.

The refractions for zenith distances less than 85° were calculated by the *Tabulæ Regiomontanæ*. The modern Greenwich observations are best represented by the refractions of these tables down to zenith distances at which the observations cease to be of material value. It appeared therefore to be the safer course to use these same tables for the reduction of the old observations made in the same locality, and to regard the systematic differences which remained—after a proper determination of the latitude—between the opposite culminations of the circumpolar stars as entirely due to errors of the form and division of the quadrant, rather than to attempt to obtain at the same time by means of these differences any improvement in the refraction tables. In the case of zenith distances exceeding 85° the refractions were taken from the results of a new calculation of Argelander's observations made with the Cary circle at Königsberg, which were brought into closer accordance with the observations as well as with the main table of the *Tabulæ Regiomontanæ* by allowing for the annual period in the decrease of temperature with elevation.

To determine the index error of the quadrant, Bessel made use of seven stars, whose zenith distances he had deduced from 259 observations made with the zenith sector at Greenwich by Bradley. Two of these stars are situated in 3^h of right ascension, one in $13\frac{1}{2}^h$, and the remaining four between $17^h{\cdot}4$ and $19^h{\cdot}4$. This number and distribution of stars must be regarded as quite inadequate for a reliable determination of the index

errors. For the position "Quadrant South" Bessel availed himself also of six stars in the feet of *Gemini* which frequently occur in the observations, and whose places were previously determined by the seven zenith stars, assuming the index error determined by the latter to remain constant during a longer interval and not to be affected by a sensible daily period. These six additional stars enabled him to reduce the observations of the catalogue stars, which were made during many periods when no zenith stars were observed, by a uniform assumption with respect to the zenith point. This assumption is, however, liable to systematic error, and the results may evidently be very different from what they would have been if a series of zenith points had been determined from observations of zenith stars of nearly the same right ascension as the catalogue stars.

Fortunately, however, the observations which Bradley made with the zenith sector afford the means of supplying this want with a fair approach to completeness. Bradley observed at Greenwich not only these seven stars, but altogether 85 stars situated in a zenithal zone of 12° in breadth. The 1,427 observations of these stars were reduced for the first time (excepting only the 259 used by Bessel); and the mean zenith distances of the 85 stars were computed for 1755·0. As it was found that there still remained some large gaps in several hours of right ascension, the reduction of the sector observations was further extended, first to another series of Greenwich observations never before reduced viz. that made of Maskelyne in 1768–1786, and secondly to the Wanstead series,* omitting from these, however, for the present purpose, the later observations of those stars of which a great number of observations occurred in the earlier years of the series. The reduction from Wanstead zenith to Greenwich zenith having been carefully effected, a combined catalogue was obtained of very trustworthy zenith distances of 130 stars. This catalogue rested upon about 4,000 observations. Of these 130 stars 114 occur also in the quadrant observations. They are very fairly distributed over the right ascensions, except for a gap from $14\frac{1}{2}^h$ to $16\frac{3}{4}^h$; so that they afford ample means for the determination of accurate and homogeneous zenith points for a great number of periods.

From the observations made during these periods the zenith distances of Maskelyne's 36 stars and of the six stars in *Gemini* were determined. By their aid the index errors could be ob-

* The reduction of these two series of observations afforded some results of interest in other respects. The discussion of Maskelyne's series led to the discovery of a considerable error in the total length of the new arc of the sector, made in 1785, and used for the determination of the amplitude in Maclear's arc of the meridian; and the discussion of the Wanstead observations showed that, contrary to general opinion, they are in perfect accordance with the now accepted value of the constant of aberration. This was also found to be the case with the observations made by Bradley and Molyneux with the zenith telescope at Kew (*Monatsberichte der Berliner Akademie der Wissenschaften*, July 1869).

tained for nearly all the remaining periods during which observations were made of the catalogue stars, but not of zenith stars.*

The zenith distances of the catalogue stars so obtained were reduced to the epoch 1755·0 in the same manner as the right ascensions.

The greater accuracy of the different steps in the reduction has produced also in the case of the zenith distances a considerable improvement in the agreement between the different observations. In the new reduction five observations of zenith distances have the same weight as seven in the old reduction. The improvement is relatively somewhat less than in the case of the right ascensions. This is due to the fact that in the old reduction the zenith distances were free from one source of error, which materially contributed to the total probable error of the right ascensions, viz. personal equation, for all the observations of zenith distances were made exclusively by the assistant.

It still remained to clear the zenith distances as far as possible from the systematic errors depending upon the figure and division of the quadrant. These errors were investigated by the following methods:—

(1) By a comparison of the upper and lower culminations of the circumpolar stars (combined with a discussion of the latitude, which will be referred to further on).

(2) By means of the transits observed with the quadrant. The manuscript journals contain the records of about 2,000 transits of stars over the vertical wires of the instrument, nearly all of which were observed in the position "Quadrant South." These observations afford the means of effecting an approximate determination of the deviations of the limb from a plane.

(3) By a comparison of the two sets of divisions of the quadrant, half of the systematic difference between the two divisions being finally applied to the results derived from the outer division alone.

(4) For zenith distances from 29° to 73° by the discussion of the observations of the Sun.

The errors which seemed to be due to the actual division proved to be generally moderate, but the limb appears to have had a considerable deviation from a plane at two places, viz. to a small extent at about 8° zenith distance, and to a larger amount at a part fortunately already beyond the range of accurate observations, viz. at 88° zenith distance. The error of figure seems to have been considerably increased by the removal of the quadrant in September 1753 from its northern to its southern position. Two different tables of corrections corresponding to the two positions

* During a considerable portion of the whole period covered by the observations, the Sun, Moon, and planets were alone observed with the quadrant, without any stars, so that no independent determination of the zenith point can be made for these observations. This occurs principally after the year 1755.

of the instrument have therefore been drawn up and used in the final correction of the zenith distances.

The equinox and the latitude were obtained as follows :—

To determine the absolute right ascensions, the observations of the Sun made with the transit instrument, 1750–1762, and with the new quadrant, 1753–1762, were reduced with the same data as the catalogue stars and compared with Hansen's tables. The equations resulting from these comparisons in both co-ordinates were treated by the method of least squares. The correction so found for the provisionally adopted system of right ascensions (*i.e.* that of the *Fundamenta*) was $0^s{\cdot}056$. This correction was applied to all the right ascensions of the catalogue. It is to be noticed, however, that no great weight is to be attached to it. Unfortunately, for nearly all the equinoxes after 1756·5 the index error of the quadrant can be determined in only a very unsatisfactory manner, or not at all, no stars having been observed for months before and after the equinox. An additional uncertainty is also attached to any result derived from Bradley's solar observations by the fact that the instruments were not protected from the Sun's rays. An attempt was made to obtain some sort of determination of the effect of the Sun upon the instruments by a comparison of Maskelyne's observations made before and after the use of a protection. But this protection was not very effective, and it would obviously be quite unsafe to apply a correction, obtained from such a comparison, to Bradley's observations, which were made under different conditions in several essential respects, and especially as regards the arrangement of the shutters.

By a careful discussion of the zenith distances of about 450 circumpolar stars the colatitude was found to be $38° 31' 21''{\cdot}28$; and this value was used in transforming the observed zenith distances into declinations.

The result of the modern determinations, 1836–1860, for the present position of the transit circle is $38° 31' 21''{\cdot}8$, which corresponds to $38° 31' 21''{\cdot}75$ for the position of the quadrant. The difference amounts, therefore, to $0''{\cdot}47$. This at first sight seems rather large, having regard to the great number of stars and observations upon which each determination is founded. Dr. Auwers points out, however, three considerations, which seem sufficient to afford a satisfactory explanation :—

(1) The old determination depends entirely upon direct observations made in a room with narrow shutters, in which some stratification of temperatures could easily have been produced and maintained.

(2) The new value $38° 31' 21''{\cdot}8$ is the mean of a direct result and a reflexion result which differ considerably. This difference was changed by enlarging the shutters from six inches to three feet by no less than $0''{\cdot}86$, the result of the direct observations being changed by $0''{\cdot}51$, or more than the whole difference

between the old value and the mean value derived from the observations, 1836–1860.

(3) The observations since 1860 show, in the mean $\frac{1}{2}$ (R+D), a tendency to somewhat diminish the value 38° 31′ 21″·8 obtained from the observations of the preceding fourteen years, and therefore to lessen the discordance from Bradley's value. Taking all these matters into consideration, the agreement of the value of the latitude derived from Bradley's observations with the modern determinations may be regarded as being quite as close as could reasonably be expected. There certainly exist no grounds for the speculations on the variability of the latitude which have been founded upon the difference between Bessel's value and the later determinations of the latitude of Greenwich.

The systematic corrections to the declinations of the *Fundamenta* resulting from the change in the adopted value of the latitude and from the corrections applied to the reduced readings of the quadrant shift the declinations generally to the south by quantities varying from 0″·01 to 1″·65, except in the case of extreme southern declinations where the correction somewhat exceeds this limit. To these systematic corrections are to be added the systematic corrections to Bessel's zenith points, which vary with the right ascension and shift the declinations to the south in the first twelve hours to an extent which does not exceed 1″, and to the north in the last twelve hours to a somewhat greater extent. As a consequence of the total effect of these corrections the new declinations are on the average 2″ more to the south than those of the *Fundamenta* in the first twelve hours, while there is a very close agreement between 14^h and 21^h.

With respect to the single stars, the difference between the new and the old declinations amounts to 3″·0 or more in 174 instances, viz. it lies between—

3″·0	and	4″·0	in the case of	96 stars
4·0	„	5·0	„	27 „
5·0	„	6·0	„	19 „

and exceeds 6″ in the case of 32 stars. Among the discrepancies exceeding 6″ several corrections of parts of the vernier (13″·2) or minutes of arc are included. If we omit the systematic differences, the comparison is of course more favourable in the first twelve hours to Bessel's catalogue; the total number of accidental differences exceeding 3″ then amounts to about 100.

Having now described the methods adopted in the new reduction and mentioned some of the principal results, it only remains to refer to the form of publication.

The complete work (of which only the escond volume has been published at present) will consist of three volumes, the contents of which are as follows:—

Vol. i. Determination of the constants of the instruments and of their position-corrections. Reduction of the right ascensions of the 36 fundamental stars and of the pole-star. Reduction of the solar observations. Reduction of the observations with the zenith sector. Determination of the equinox and of the latitude. Reduction of the planetary observations.

Vol. ii. Results of the single observations of right ascension and zenith distance. The right ascensions and zenith distances are contained in separate catalogues, which give, for every observation of every star, the date, the observer, the reduction from the apparent place to 1755·0, the mean right ascension and zenith distance for this epoch, and the weight.

This volume also contains the long and elaborate list of errors detected in the observations. There is also a discussion of the principal errors.

Vol. iii. This volume, which contains the star catalogue, consists of an Introduction and three Parts.

The Introduction contains, besides other matters, the specially determined values of about 60 stars which were observed in both positions of the quadrant, the single results of both culminations of 455 circumpolar stars, the explanation of some 300 cases of marked discordance between the new places and those of the *Fundamenta*, an investigation of the systematic differences between the new places and those of the *Fundamenta*, and a collection of all the existing determinations for the 46 new stars which do not occur in the *Fundamenta*, with the deduction of the most probable proper motions.

The First Part contains the catalogue, with the precessions for the three epochs 1755, 1810, and 1865, a comparison with the *Fundamenta*, references to the occurrences of the stars in the contemporaneous catalogues of Lacaille and Mayer, and also in that of Piazzi, in Airy's five Greenwich catalogues, and in the Berlin catalogue. A complete list of references is also given for all the double stars which occur, the distance and position-angle of the comparison being given as far as possible for the epoch 1755.

The Second Part contains the logarithms of Bessel's quantities a, b, c, d and a', b', c', d' for the two epochs 1755 and 1865.

The Third Part contains the reduction of Bradley's places to 1865, the new catalogue for 1865, and the comparison of the two catalogues.

The printing was undertaken by the Academy of St. Petersburg. The manuscript of the second volume was sent to the printers in 1877, but four years were occupied in its publication, so that it was not in the hands of astronomers till 1882. A year's delay was caused by Dr. Auwers's absence to observe the transit of *Venus*. On his return from the Straits of Magellan in 1883 the manuscript of the third volume was sent to the printers. More than four years have been occupied in passing it through

the press. Although not yet published, it is now all but complete, and its publication may be expected very soon.

Several of the six special investigations which will form vol. i. are already worked out, but none of them are completely ready for the press. Dr. Auwers is at present engaged upon the publication of the German observations of the transit of *Venus*, and although this work progresses rapidly the mass of material is so great that it cannot be completed for three or four years. It is not probable, therefore, that the manuscript of vol. i. of the new reduction will be ready for press for some years.

The whole of the calculations (excepting the reduction of the planetary observations, which formed no part of the original scheme) were completed in 1876, and in the following year the manuscripts of vols. ii. and iii. were ready for press.

It is much to be regretted that the printing should have progressed so slowly. The consequences of the delay have been mitigated, however, by the liberality with which Dr. Auwers has placed his results at the disposal of all who were in need of them, so that they have been for years in the possession of those to whom it was of most importance that they should be available for use. Among the institutions to which the catalogue has been communicated are the Greenwich Observatory and the *Nautical Almanac* Office. Professor Safford was enabled to employ the new reduction in his catalogue of the declinations of 2,018 stars published in 1879, as also was Professor Newcomb in his catalogue of 1,098 standard stars published in 1881. Dr. Auwers himself has made great use of the new reduction in his "Fundamental Catalogue for the Zone Observations," published in 1879, and also in his catalogue of 83 southern stars, which was published subsequently. It is also used in the Pulkowa catalogue of 3,542 stars for 1855·0, and in the catalogue of the Paris Observatory which has just been issued.

I can scarcely hope that I have succeeded in giving a just idea of the magnitude of the undertaking carried out by Dr. Auwers, or of the manner in which it has been executed, but I trust that what I have said will at least have shown the continual necessity for experienced judgment and delicate treatment at every stage of the work, and the great interest and value of the results. By his previous reduction of Piazzi's observations and his other investigations connected with star catalogues, Dr. Auwers had shown himself to be possessed of peculiar qualifications for the performance of this great task; and we may feel assured that he has spared no effort to attain the highest degree of accuracy that the present state of astronomy could enable us to reach.

The Council have considered that, although but one volume of the work has as yet been published, they ought no longer to delay their recognition of the value of Dr. Auwers's fundamental

contribution to the progress of astronomy; and, as the countrymen of Bradley, they have felt especially desirous to give public expression at the earliest moment, without waiting for the completion of the publication, to their sense of obligation to Dr. Auwers for his excellent and masterly treatment of the observations of our own great astronomer.

The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms:

Dr. Huggins, in transmitting this medal to Dr. Auwers, and conveying to him our congratulations upon the completion of so great a work, may I ask you at the same time to express to him, not only our admiration of the manner in which the most refined skill has been combined with the most patient care in its performance, but also our personal acknowledgments for the years of laborious industry in which, with untiring zeal, he has devoted his time and powers to the not unworthy task of applying to the advance of modern astronomy the concluding labours of Bradley's useful life.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Arthur Cayley, Esq., M.A., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
J. W. L. Glaisher, Esq., Sc.D., F.R.S.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

Treasurer.

A. A. Common, Esq., F.R.S.

Secretaries.

E. B. Knobel, Esq.
Lieut.-Col. G. L. Tupman, R.M.A.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

Capt. W. de W. Abney, R.E., F.R.S.
Hon. Sir James Cockle, M.A., F.R.S.
Warren de la Rue, Esq., M.A., Ph.D., D.C.L., F.R.S.
A. M. W. Downing, Esq., M.A.
Edwin Dunkin, Esq., F.R.S.
N. E. Green, Esq.
George Knott, Esq., B.A., LL.B.
E. W. Maunder, Esq.
Capt. William Noble.
Rev. S. J. Perry, D.Sc., F.R.S.
Lieut.-Gen. J. F. Tennant, R.E., F.R.S.
H. H. Turner, Esq., M.A., B.Sc.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Arthur Berry, B.A., King's College, Cambridge; and
The Rev. Walter Edward Stewart, M.A., 1 Banks Terrace, Croft-on-Tees, Darlington,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

Thomas Dallmeyer, 18 Bloomsbury Street, W.C. (proposed by Capt. W. de W. Abney);
George Wilson Heath, F.R.G.S., Scientific Instrument Manufacturer, Bexley, Kent (proposed by J. R. Jones);
Alfred Robert Johnson, M.A., St. John's College, Cambridge (proposed by H. H. Turner);
Reginald Carter Nelson, Solicitor, 19 Roker Terrace, Sunderland (proposed by Cuthbert Hutchinson);
Sir Henry Thompson, M.B., 35 Wimpole Street, W. (proposed by A. A. Common);
John Walther, M.D., C.M. Edin., West House, Eastbourne (proposed by John Browning).

The Numerical Lunar Theory.

(*Extract from a letter from Sir G. B. Airy to Mr. Knobel.*)

In my Numerical Lunar Theory, Section VI., page 76, I remarked that there were difficulties in the lunar theory which I had not overcome; and which I naturally attributed to some error of my own mathematical work. I have now discovered the error.

In page 11, I assumed the existence of a solar term, with a coefficient which I called M, and which I supposed to exercise an influence on the lunar motions. I was not justified in this assumption, and I withdraw it entirely.

It is necessary now to modify the text of some of the following sections, and to substitute in several places new piles of figures for those which I had furnished. The work will be considerable, and must be done, in a great measure, by myself. However, I have already taken some steps for effecting it. I can only report at present that page 11 is to be entirely expunged. But I hope this day to give instructions to computers.

The White House, Croom's Hill, Greenwich Park:
1888, *March* 23.

Orbit of the Binary Star λ *Ophiuchi.* By Professor S. Glasenapp.

(*Communicated by E. Dunkin, F.R.S.*)

The observations of this binary star, made by several observers during the last sixty-two years, show a direct motion for the component. This motion can be easily seen from the following measurements which we select from a long series of observations :—

Epoch.	θ	σ	Observer.
1825·51	331°·4	0″·8	W. Struve.
1828·64	341·3	0·8	J. Herschel, W. Struve.
1840·55	357·9	1·0	O. Struve, Bishop.
1853·52	13·3	1·3	O. Struve, Dawes, Smyth.
1861·61	20·9	1·3	O. Struve, Mädler.
1868·57	27·1	1·4	O. Struve, Dunér, Dembowski, Main.
1877·51	33·6	1·5	O. Struve, Dembowski, Jedrzejewicz, Doberck.
1886·58	42·0	1·5	A. Hall, Jedrzejewicz.

Now the observations of W. Herschel (*Phil. Trans.* 1804, Part II. p. 374) :—

1783·18	75°·5	±0″·50
1802·39	69°·3	—

indicate a retrograde motion of about 6° in 19 years; therefore it is evident that one of these observations or both of them are erroneous. Several astronomers have tried to restore these observations, and have supposed that the true measurements may be read as follows :—

Year.	W. Struve.	Mädler, Hind, Dawes.	O. Struve.	R. Engelmann.	Flammarion.
1783	255°·5	75°·5	75°·5	205°·5	284°·5
1802	69·3	249·3	110·7	249·3	290·7

As these observations are of great value in the investigation of the orbit of λ *Ophiuchi*, I believe that the following considerations may throw some light on the true positions of the component star in these observations.

I find that W. Herschel's original observations are noted as follows:—

For 1783 ... ... 14° 30′ *nf* ($\theta = 75°{\cdot}50$)
For 1802 ... ... 20° 41′ *sf* ($\theta = 110°{\cdot}7$)

and that the angles are counted from the parallel-circle. If we suppose that only an error in writing has occurred in the entry of the observations, and that instead of *nf* we could put *sf*, or *np*, or *sp*, we should obtain for each epoch four positions of the component star; one of these will be the true observation. These values are the following:—

If we write *nf* we shall have 75°·5 for 1783; 69°·3 for 1802.
„ *sf* „ 104·5 „ 110·7 „
„ *sp* „ 255·5 „ 249·3 „
„ *np* „ 284·5 „ 290·7 „

As we do not know which of these four values for each epoch is the true one, we may suppose that the true observations are included in the following 16 combinations of the preceding angles:—

No.	1783.	1802.	No.	1783.	1802.
	°	°		°	°
1	75·5	69·3	9	255·5	69·3
2	75·5	110·7	10	255·5	110·7
3	75·5	249·3	11	255·5	249·3
4	75·5	290·7	12	255·5	290·7
5	104·5	69·3	13	284·5	69·3
6	104·5	110·7	14	284·5	110·7
7	104·5	249·3	15	284·5	249·3
8	104·5	290·7	16	284·5	290·7

Eight of these combinations, Nos. 1, 5, 9, 10, 11, 13, 14, and 15 indicate a retrograde or a very rapid direct motion, which is not confirmed by the observations of the last 62 years; therefore these combinations must be rejected as improbable.

Four combinations, Nos. 3, 4, 7, and 8, indicate a very rapid direct motion, which is not confirmed by the observations of the last 62 years; they must also be rejected as improbable.

Finally, the two combinations Nos. 6 and 16 indicate a too small direct motion, which is also not confirmed by the later observations; for the same reason they must also be rejected.

There are left only the two following combinations under Nos. 2 and 12 :—

	1783.	1802.
No. 2	75°·5	110°·7
No. 12	255°·5	290°·7

which indicate a possible direct motion of 35° in 19 years. If we remember that the distance in 1783 is equal to 0″·5 we can only admit the last combination, No. 12. Indeed, the observations of the last 62 years indicate an increase of distance between the components, and when θ will be equal to 75° the distance may be probably 1″·7, but not 0″·5 as it was in 1783. Therefore, only one combination, which is noted under No. 12, can be admitted as the most probable on the supposition that W. Herschel's observations are affected with an error in writing.

N.B.—The distance in 1783 is only an estimate, and may have been as large as 1″·5.

If we add these two observations (combination No. 12) to the observations made during the last 62 years, we obtain the beautiful series of measurements, contained in the following table, in which the angles of position are reduced to the circle of 1900.

Epoch.	θ	σ	Epoch.	θ	σ
1783·18	254°·9	±0″·5 (est.)	1853·52	13°·3	1″·3
1802·39	290·2	—	1861·61	20·9	1·3
1825·51	331·4	0·8	1868·57	27·1	1·4
1828·64	341·3	0·8	1877·51	33·6	1·5
1840·55	357·9	1·0	1886·58	42·0	1·5

From these observations we obtain the following system of elements of the orbit :—

T = 1787·9	λ = 152°·5 Eq. 1900
U = 373·5 years	i = 38°·1
n = +0°·9638	e = 0·4424
Ω = 105°·5 Eq. 1900	a = 1″·53

These elements represent very well the above-mentioned observations. The following table contains the comparison of the computed values with the observed :—

Epoch.	θ_o	θ_c	$\theta_o-\theta_c$	σ_o	σ_c	$\sigma_o-\sigma_c$
1783·18	254°·9	251°·5	+3°·4	±0″·5	0″·8	−0″·3
1802·39	290·2	294·1	−3·9	—	—	—
1825·51	331·4	334·4	−3·0	0·8	1·0	−0·2
1828·64	341·3	339·3	+2·0	0·8	1·0	−0·2
1840·55	357·9	356·4	+1·5	1·0	1·1	−0·1
1853·52	13·3	12·4	+0·9	1·3	1·2	+0·1
1861·61	20·9	20·9	0·0	1·3	1·3	0·0
1868·57	27·1	27·5	−0·4	1·4	1·3	+0·1
1877·51	33·6	35·0	−1·4	1·5	1·4	+0·1
1886·58	42·0	41·8	+0·2	1·5	1·5	0·0

These elements must be certainly considered as a first approximation only.

Observatoire de l'Université Impériale,
St. Petersburg: February 1888.

Southern Double Stars. By the Rev. S. J. Johnson, M.A.

Although there do not seem to be any published measures of southern double stars at very low altitudes in this country, yet there are a few interesting objects which do not deserve to be neglected, and of which measures not quite without value can be got by an observer situated on the extreme south coast of England, if he will watch for the few favourable opportunities of a clear horizon when the star is near its highest attainable altitude in our land. The following are a few specimens of objects of this kind taken with a filar micrometer on a $3\frac{1}{4}$-inch equatorial during the last few years. The mean of four measures in each case is given.

No.	Year.		Position-angle.	Distance.
			°	″
1	1881·92	ω Fornacis	240·3	10·4
2	1882·12	H 3945	66·9	—
3	1886·34	3 (κ) Centauri	109·4	7·6
4	1887·23	ξ Antliæ	209·0	10·0
5	1887·37	*f* Hydræ	189·4	12·4

Distance measurements of (2) could not be got. Very little illumination could be used. The colours of (2) are fine and prominent: red, blue. The companion of 3 (κ) *Centauri* seems to have a bluish tint. Measures of ξ *Antliæ* were rather discordant, but the mean good. The lat. of this place is about 50° 46′ 10″.

Melplash Vicarage, Dorset:
1888, *March* 7.

On the Orbit of 70 (*p*) *Ophiuchi.* By J. E. Gore.

As none of the orbits hitherto published for this interesting binary star represent recent measures satisfactorily, I have computed an orbit, using all available measures from 1819 to 1887, about 247 in number, and find the following provisional elements:—

Elements of 70 *Ophiuchi.*

P = 87·84 years.	Ω = 120° 5′ (1880·0)
T = 1807·65	λ = 171° 45′
e = 0·4912	*a* = 4″·50
γ = 58° 28′	*u* = −4°·098

The following is a comparison between the recorded measures and the positions computed from the above elements. The observed position-angles have been corrected for the effect of precession to 1880·0 :—

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1779·76	Sir W. Herschel	89°·45	99°·38	(−9°·93)	3″·6	5″·23	−1″·63
1780·49	,,	...	...	...	4·4	5·12	−0·72
1781·73	,,	98·66	96·50	+2·16			
1802·25	,,	335·67	337·94	−2·27			
1804·41	,,	318·38	319·37	−0·99			
1819·64	Struve	168·17	168·12	+0·05			
1820·77	,,	159·87	162·15	−2·28			
1821·31	Herschel & South	155·88	159·73	−3·85	3·68	2·95	+0·73
1821·74	Struve	157·28	157·92	−0·64			
1822·42	Herschel & South	154·48	154·37	+0·11	4·85	3·27	+1·58
1822·64	Struve	153·58	153·86	−0·28			
1823·35	Herschel & South	153·29	152·23	+1·06			
1825·57	,,	147·80	146·18	+1·62	4·765	4·00	+0·765
1827·02	Struve	144·81	143·00	+1·81	4·37	4·32	+0·05
1827·51	Herschel & South	141·71	142·06	−0·35	5	4·42	+0·58
1828·71	Struve	139·92	139·87	+0·05	4·78	4·68	+0·10
1829·59	,,	137·72	138·40	−0·68	5·08	4·84	+0·24
1830·36	Herschel & South	137·83	137·30	+0·53	5·95	4·98	+0·97
1830·41	Bessel	135·33	137·22	−1·89	5·45	4·99	+0·46
1830·57	Dawes	137·13	136·98	+0·15	5·53	5·02	+0·51
1830·69	Bessel	135·43	136·79	−1·36	5·51	5·01	+0·50
1830·76	Smyth	136·17	136·68	−0·51	5·43	5·06	+0·37
1830·84	Struve	135·43	136·56	−1·13	5·31	5·08	+0·23
1831·52	Herschel & South	135·83	135·51	+0·32	5·97	5·19	+0·78
1831·68	Struve	134·43	135·31	−0·88	5·41	5·22	+0·19
1832·55	Dawes	132 44	134·20	−1·76	5·71	5·37	+0·34
1832·57	Herschel & South	135·24	134·18	+1·06	5·49	5·37	+0·12
1832·75	Struve	133·64	133·95	−0·31	5·55	5·39	+0·16
1833·42	Dawes	132·54	133·01	−0·47	6·14	5·49	+0·65
1833·59	Smyth	132·24	132·78	−0·54	6·0	5·53	+0·47
1834·47	Struve	130·85	131·72	−0·87	5·85	5·65	+0·20
1834·57	Dawes	130·35	131·60	−1·25	6·12	5·66	+0·46
1835·56	Smyth	130·36	130·46	−0·10	5·97	5·74	+0·23
1835·60	,,	130·56	130·42	+0·14	6·11	5·75	+0·36
1835·60	Struve	130·46	130·42	+0·04	6·10	5·75	+0·35

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	"	"	"
1836·50	Encke	127·76	129·42	−1·66	6·46	5·91	+0·55
1836·65	Herschel & South	129·06	129·26	−0·20	6·97	5·93	+1·04
1836·66	Struve	129·26	129·25	+0·01	6·13	5·93	+0·20
1836·81	Smyth	128·36	129·10	−0·74	6·19	5·95	+0·24
1837·46	Encke	127·97	128·42	−0·45	6·72	6·06	+0·66
1837·64	Smyth	127·27	128·23	−0·96	6·26	6·06	+0·20
1838·51	„	126·27	127·33	−1·06	6·25	6·13	+0·12
1838·56	Encke	126·37	127·28	−0·91	6·63	6·13	+0·50
1839·51	„	124·98	126·35	−1·37	6·78	6·25	+0·53
1839·65	Dawes	125·58	126·22	−0·64	6·55	6·27	+0·28
1839·87	Encke	125·48	126·00	−0·52	6·34	6·30	+0·04
1840·35	Kaiser	127·68	125·55	+2·13	6·00	6·32	−0·32
1840·59	Dawes	124·58	125·33	−0·75	6·62	6·33	+0·29
1840·75	O. Struve	126·88	125·18	+1·70	6·59	6·34	+0·25
1841·44	Mädler	125·19	124·54	+0·65	6·45	6·44	+0·01
1841·65	O. Struve	125·69	124·34	+1·35	6·65	6·43	+0·22
1841·68	Dawes	123·19	124·31	−1·12	6·63	6·42	+0·21
1841·74	Kaiser	123·19	124·26	−1·07	6·53	6·42	+0·11
1842·39	Mädler	124·19	123·65	+0·54			
1842·53	Dawes	123·09	123·53	−0·44	6·72	6·46	+0·26
1842·55	Smyth	122·19	123·51	−1·32	6·64	6·46	+0·18
1842·59	Kaiser	122·39	123·48	−1·09	6·48	6·47	+0·01
1842·62	Challis	124·79	123·46	+1·33	5·86	6·47	−0·61
1842·66	Mädler	124·49	123·42	+1·07	6·25	6·47	−0·22
1842·70	O. Struve	124·49	123·38	+1·11	6·62	6·47	+0·15
1843·53	Mädler	123·10	122·64	+0·46	6·42	6·52	−0·10
1843·56	Challis	123·30	122·62	+0·68	6·69	6·52	+0·17
1843·72	Mädler	122·30	122·48	−0·18	6·43	6·53	−0·10
1844·57	„	121·80	121·72	+0·08	6·48	6·58	−0·10
1844·59	Challis	121·30	121·70	−0·40	5·96	6·58	−0·62
1844·71	O. Struve	121·30	121·60	−0·30	6·62	6·59	+0·03
1845·43	Herschel & South	120·61	120·97	−0·36	6·77	6·62	+0·15
1845·54	Mädler	120·61	120·88	−0·27	6·58	6·62	−0·04
1845·68	O. Struve	120·71	120·76	−0·05	6·55	6·62	−0·07
1846·01	Jacob	120·21	120·48	−0·27	6·83	6·63	+0·20
1846·46	Hind	119·91	120·08	−0·17	6·14	6·64	−0·50
1846·56	Durham Obs.	116·91	120·00	−3·09	7·43	6·64	+0·79
1846·57	Mädler	119·61	120·00	−0·39	6·64	6·64	0·0
1846·73	O. Struve	121·11	119·86	+1·25	6·61	6·64	−0·03

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	″	″	″
1847·45	Durham Obs.	117·02	119·25	−2·23	7·19	6·66	+0·53
1847·48	Smyth	119·52	119·23	+0·29	6·8	6·66	+0·14
1847·59	Mitchell	120·12	119·14	+0·98	5·53	6·66	−1·13
1847·76	O. Struve	119·52	118·99	+0·53	6·50	6·66	−0·16
1848·12	Dawes	118·62	118·68	−0·06	6·80	6·67	+0·13
1848·50	Mädler	118·03	118·35	−0·32	6·83	6·65	+0·18
1848·52	Bond	117·93	118·32	−0·39	6·9	6·65	+0·25
1848·52	,,	117·53	118·32	−0·79	6·8	6·65	+0·15
1848·79	O. Struve	118·33	118·11	+0·22	6·78	6·65	+0·13
1849·78	,,	117·63	117·27	+0·36	6·54	6·64	−0·10
1850·48	Jacob	114·94	116 67	−1·73	6·86	6·63	+0·23
1850·64	Mädler	116·54	116·53	+0·01	6·94	6·63	+0·31
1851·47	,,	115·24	115·83	−0·59	6·67	6·62	+0·05
1851·67	O. Struve	115·24	115 66	−0·42	6·52	6·62	−0·10
1851·74	Mädler	115·34	115·60	−0·26	6·67	6·62	+0·05
1852·44	Smyth	114·75	115·01	−0·26	...	6·61	
1852·67	O. Struve	114·85	114·82	+0·03	6·55	6·61	−0·06
1852·73	Mädler	114·55	114·77	−0·22	6·56	6·61	−0·05
1852·74	Jacob	113·85	114·77	−0·92	6·73	6·61	+0·12
1853·54	Dembowski	116·25	114·05	+2·20	6·45	6·60	−0·15
1853·60	Dawes	116·45	114·00	+2·45	6·48	6·60	−0·12
1853·76	Mädler	113·15	113·86	−0·71	6 56	6·59	−0·03
1853·78	O. Struve	113·45	113·84	−0·39	6·47	6·59	−0·12
1854·08	Jacob	113·46	113·58	−0·12	6·36	6·58	−0·22
1854·58	Dembowski	113·36	113·15	+0·21	6·26	6·56	−0·30
1854·68	Mädler	113·16	113·06	+0·10	6·31	6·56	−0·25
1854·69	O. Struve	112·66	113·06	−0·40	6·54	6·56	−0·02
1854·73	Dawes	113·56	113·02	+0·54	6·33	6·56	−0·23
1855·21	Dembowski	112·96	112·59	+0·37	6·52	6·53	−0·01
1855·45	Secchi	111·46	112·30	−0·84	6·25	6·52	−0·27
1855·66	O. Struve	111·76	112·05	−0·29	6·49	6·50	−0·01
1855·66	Dawes	112·46	112·05	+0·41	6·51	6·50	+0·01
1855·69	,,	113·06	112·01	+1·05	6·46	6·50	−0·04
1856·12	Jacob	111·77	111·87	−0·10	6·45	6·47	−0·02
1856·37	,,	111·27	111·57	−0·30	6·39	6·45	−0·06
1856·50	Mädler	111·37	111·35	+0·02	6·32	6·44	−0·12
1856·63	Dembowski	111·57	111·33	+0·24	6·40	6·43	−0·03
1856·73	O. Struve	111·57	111·22	+0·35	6·37	6·43	−0·06
1857·13	Jacob	110·47	110·66	−0·19	6·46	6·40	+0·06

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	′	″	″
1857·42	Fletcher	112·18	110·46	+1·62	6·36	6·38	−0·02
1857·57	Dawes	109·88	110·29	−0·41	6·38	6·37	+0·01
1857·58	,,	110·08	110·28	−0·20	6·52	6·37	+0·15
1857·63	Dembowski	109·38	110·22	−0·84	6·31	6·37	−0·06
1857·67	Morton	109·98	110·19	−0·21	6·15	6·37	−0·22
1857·69	O. Struve	109·98	110·18	−0·20	6·40	6·37	+0·03
1858·12	Jacob	109·58	109·88	−0·30	6·10	6·33	−0·23
1858·39	Morton	108·48	109·68	−1·20	6·08	6·30	−0·22
1858·44	Dembowski	109·18	109·65	−0·47	6·09	6·30	−0·21
1858·63	Mädler	108·78	109·47	−0·69	5·94	6·28	−0·34
1858·72	O. Struve	108·68	109·38	−0·70	6·21	6·27	−0·06
1859·68	,,	108·38	108·45	−0·07	6·19	6·21	−0·02
1859·72	Dawes	109·18	108·41	+0·77	6·24	6·21	+0·03
1859·75	Auwers	108·88	108·38	+0·50	6·61	6·21	+0·40
1860·61	Secchi	106·19	107·53	−1·34	6·07	6·12	−0·05
1860·74	Auwers	107·79	107·40	+0·39	6·49	6·11	+0·38
1861·46	Main	106·90	106·65	+0·25	5·89	6·03	+0·14
1861·63	O. Struve	106·30	106·48	−0·18	5·88	6·01	−0·13
1861·97	Mädler	105·90	106·12	−0·22	5·85	5·97	−0·12
1862·62	Dembowski	105·40	105·43	−0·03	5·73	5·90	−0·17
1862·72	Mädler	105·10	105·33	−0·23	5·70	5·89	−0·19
1862·77	O. Struve	105·10	105·28	−0·18	5·85	5·88	−0·03
1863·5	Wash. Obs.	106·11	104·45	+1·66	5·19	5·86	−0·67
1863·5	,,	106·81	104·45	+2·36	5·74	5·86	−0·12
1863·5	,,	106·21	104·45	+1·76	6·04	5·86	+0·18
1863·5	,,	105·81	104·45	+1·36	5·87	5·86	+0·01
1863·5	,,	104·91	104·45	+0·46	5·72	5·86	−0·14
1863·5	,,	104·71	104·45	+0·26	5·74	5·86	−0·12
1863·51	Dembowski	104·11	104·45	−0·34	5·60	5·80	−0·20
1863·55	Romberg	104·41	104·41	0·0	5·76	5·80	−0·04
1864·48	Engelmann	104·71	103·35	+1·36	5·42	5·67	−0·25
1864·60	Dembowski	103·41	103·21	+0·20	5·46	5·67	−0·21
1865·51	,,	102·22	102·13	+0·09	5·37	5·53	−0·16
1865·53	Romberg	104·42	102·11	+2·31	5·30	5·53	−0·23
1865·55	,,	103·82	102·08	+1·74	5·24	5·53	−0·29
1865·62	Kaiser	100·52	101·99	−1·47	5·31	5·52	−0·21
1865·72	O. Struve	102·62	102·86	−0·24	5·32	5·50	−0·18
1865·80	,,	101·12	101·76	−0·64	5·26	5·49	−0·23
1866·49	Talmage	101·73	100·86	+0·87	5·26	5·40	−0·14

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	"	"	"
1866·61	Secchi	101·03	100·71	+0·32	5·27	5·38	−0·11
1866·66	O. Struve	100·33	100·65	−0·32	5·29	5·38	−0·09
1867·01	Dembowski	100·97	100·19	+0·78	5·17	5·32	−0·15
1867·41	Main	98·03	99·64	−1·61	5·33	5·26	+0·07
1867·44	Knott	99·73	99·60	+0·13	5·22	5·25	−0·03
1867·52	Talmage	100·43	99·49	+0·94			
1868·46	Dembowski	98·94	98·19	+0·75	4·85	5·10	−0·25
1868·46	Main	97·74	98·19	−0·45	5·27	5·10	+0·17
1868·56	Knott	98·44	98·04	+0·40	4·97	5·08	−0·11
1868·64	Talmage	101·04	97·92	+3·12	5·49	5·07	+0·42
1868·69	Main	101·74	97·85	+3·89	4·96	5·07	−0·11
1868·71	O. Struve	99·04	97·82	+1·22	4·69	5·06	−0·37
1868·72	Dunér	97·44	97·80	−0·36	4·83	5·06	−0·23
1868·90	Brünnow	97·94	97·53	+0·41	4·92	5·03	−0·11
1869·60	Dembowski	96·44	96·48	−0·04	4·71	4·90	−0·19
1869·61	Talmage	100·14	96·46	+3·68	5·31	4·90	+0·41
1869·69	Dunér	96·84	96·34	+0·50	4·58	4·88	−0·30
1870·30	Gledhill	94·65	95·35	−0·70	4·6	4·78	−0·18
1870·45	Main	95·05	95·10	−0·05	4·83	4·75	+0·08
1870·47	,,	94·15	95·07	−0·92	4·80	4·75	+0·05
1870·50	,,	96·35	95·03	+1·32	4·84	4·74	+0·10
1870·51	Dembowski	94·45	95·01	−0·56	4·56	4·74	−0·18
1870·60	Talmage	94·35	94·87	−0·52	4·62	4·72	−0·10
1870·72	Gledhill	93·15	94·64	−1·49	4·3	4·70	−0·40
1870·79	Main	96·55	94·52	+2·03	4·65	4·69	−0·04
1871·48	Wilson & Seabroke	92·75	93·31	−0·56	4·6	4·56	+0·04
1871·49	,,	92·45	93·29	−0·84	4·60	4·56	+0·04
1871·50	Gledhill	92·85	93·27	−0·42	4·4	4·56	−0·16
1871·53	Dembowski	92·55	93·22	−0·67	4·27	4·55	−0·28
1871·55	Talmage	96·65	93·18	+3·47	4·34	4·55	−0·21
1871·59	Knott	94·87	93·11	+1·76	4·30	4·54	−0·24
1871·63	Gledhill	93·05	93·03	+0·02	4·4	4·53	−0·13
1871·72	Dunér	92·55	92·86	−0·31	4·20	4·52	−0·32
1871·80	Gledhill	92·05	91·98	+0·07	4·08	4·50	−0·42
1872·49	Dembowski	90·66	91·39	−0·73	4·08	4·38	−0·30
1872·49	Main	90·76	91·39	−0·63	4·28	4·38	−0·10
1872·49	Ferrari	91·46	91·39	+0·07	4·30	4·38	−0·08
1872·49	Wilson & Seabroke	...	91·39	...	4·61	4·38	+0·23
1872·50	,,	90·66	91·37	−0·71	4·32	4·38	−0·06

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	"	"	"
1872·52	Wilson & Seabroke	91·86	91·33	+0·53	4·17	4·38	−0·21
1872·54	,,	91·76	91·29	+0·47	4·07	4·37	−0·30
1872·60	O. Struve	93·56	91·17	+2·39	4·08	4·35	−0·27
1873·41	Main	88·86	89·57	−0·71	4·20	4·15	+0·05
1873·51	Dembowski	88·76	89·37	−0·61	3·89	4·13	−0·24
1873·51	Gledhill	89·46	89·37	+0·09			
1873·51	Wilson & Seabroke	88·76	89·37	−0·61	4·1	4·13	−0·03
1873·55	Talmage	84·66	89·28	(−4·62)	3·95	4·12	−0·17
1873·63	Wilson & Seabroke	88·46	89·09	−0·63	3·93	4·11	−0·18
1873·73	Main	88·66	88·36	+0·30	4·23	4·09	+0·14
1874·47	,,	88·67	87·13	+1·54	4·00	3·96	+0·04
1874·56	Dembowski	86·07	86·92	−0·85	3·66	3·94	−0·28
1874·58	Talmage	88·57	86·87	+1·70	3·67	3·94	−0·27
1874·69	O. Struve	87·37	86·59	+0·78	3·78	3·92	−0 14
1874·73	Gledhill	87·47	86·49	+0·98	3·92	3·91	+0·01
1875·52	Dembowski	83·68	84·48	−0·80	3·48	3·77	−0·29
1875·62	Wilson & Seabroke	(95·08)	84·20	(+10·88)	3·49	3·75	−0·26
1875·62	Schiaparelli	84·08	84·20	−0·12	3·44	3·75	−0·31
1875·65	Main	84·78	84·12	+0·66	3·84	3·74	+0·10
1876·52	Doberck	78·88	81·70	−2·82			
1876·54	Plummer	80·18	81·64	−1·46	3·55	3·55	0·0
1876·59	Schiaparelli	81·18	81·48	−0·30	3·34	3·54	−0·20
1876·61	Wilson & Seabroke	80·48	81·42	−0·94			
1876·61	,,	80·38	81·42	−1·04	3·37	3·54	−0·17
1876·62	Dunér	81·48	81·39	+0·09	...	3·54	
1877·51	Dembowski	77·58	78·56	−0·98	3·086	3·33	−0·244
1877·51	Flammarion	78·09	78·56	−0·47	3·22	3·33	−0·11
1877·52	Doberck	77·59	78·53	−0 94	3·46	3·33	+0·13
1877·55	Hall	75·81	78·42	−2·61	3·36	3·33	+0·03
1877·58	Jedzrejewicz	79·39	78·31	+1·08	3·180	3·32	−0·14
1877·65	Plummer	78·49	78·01	+0·48	3·39	3·30	+0·09
1877·66	Schiaparelli	77·33	78·01	−0·68	3·121	3·30	−0·179
1877·68	Cin. Obs.	78·49	77·94	+0·55	3·12	3·30	−0·18
1878·51	Dembowski	74·52	74·92	−0·40	2·966	3·13	−0·164
1878·54	Doberck	75·39	74·81	+0·58	3·03	3·12	−0·09
1879·41	Schiaparelli	69·2	71·23	−2·03	2·84	3·11	−0·27
1879·50	,,	69·83	70·87	−1·04	2·845	2·92	−0·075
1879·59	Hall	71·32	70·51	+0·81	2·93	2·90	+0·03
1879·64	Schiaparelli	67·9	70·30	−2·40	2·94	2·89	+0·05

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	"	"	"
1879·66	Jedzrejewicz	68·6	70·22	−1·62	3·039	2·89	+0·149
1880·49	Franz	62·1	66·33	(−4·23)	2·69	2·72	−0·03
1880·57	Hall	65·5	65·83	−0·33	2·74	2·70	+0·04
1880·66	Schiaparelli	64·88	65·28	−0·40	2·692	2·68	+0·012
1880·66	Jedzrejewicz	62·8	65·28	−2·48	2·75	2·68	+0·07
1881·53	Hall	60·7	59·87	+0·83	2·49	2·51	−0·02
1882·564	,,	56·4	52·80	+3·60	2·31	2·29	+0·02
1882·72	Engelmann	51·63	52·46	+0·83	2·314	2·28	+0·034
1883·49	Perrotin	45·62	46·48	−0·86	2·28	2·15	+0·13
1883·579	Young	43·20	45·75	−2·55	2·45	2·14	+0·31
1883·594	Hall	47·7	45·65	+2·05	2·28	2·14	+0·14
1883·68	Küstner	45·23	44·92	+0·31	2·511	2·11	+0·401
1883·72	Engelmann	43·64	44·61	−0·97	2·25	2·11	+0·14
1884·56	Perrotin	34·54	36·98	−2·44	2·088	2·00	+0·088
1884·588	Hall	37·6	36·71	+0·89	2·16	1·96	+0·20
1884·69	Engelmann	35·28	35·77	−0·49	2·204	1·96	+0·244
1885·566	Hall	29·5	28·24	+1·26	1·87	1·90	−0·03
1885·64	Engelmann	24·32	27·60	−3·28	2·06	1·90	+0·16
1886·528	Hall	13·8	16·64	−2·84	1·98	1·88	+0·10
1886·67	Engelmann	14·90	14·90	0·0	1·88	1·87	+0·01
1887·611	Hall	3·6	4·24	−0·64	1·93	1·83	+0·10
1887·812	Tarrant	3·49	1·97	+1·52	1·91	1·83	+0·08
1887·86	Young	2·50	1·43	+1·07	(2·35)	1·84	(+0·51)

The formulæ for the calculation of an ephemeris are as follows:—

$$u - 28\cdot14 \sin u = -4^\circ\cdot098\,(t - 1807\cdot65)$$

$$\tan \tfrac{1}{2}V = [0\cdot2335038] \tan \tfrac{1}{2}u$$

$$\tan(\theta - 120^\circ\ 5') = [9\cdot7185017] \tan(V + 171^\circ\ 45')$$

$$\rho = 4''\cdot50\,(1 - 0\cdot4912 \cos u)\,\frac{\cos(V + 171^\circ\ 45')}{\cos(\theta - 120^\circ\ 5')}.$$

Observations of the Variable Star S (10) Sagittæ By J. E. Gore.

The following are my observations of this short period variable in the year 1887. They form a continuation of the observations given in the *Monthly Notices* for March 1887.

The comparison stars are as before:—

	Mag.
11 Sagittæ	5·8
9 Sagittæ	6·6
DM + 16°, 4086	7·0

Date.	Dublin M.T. h m	Mag.	Date.	Dublin M.T. h m	Mag.
1887, Jan. 11	6 35	5·8	1887, Oct. 27	8 30	6·3
12	6 5	5·7	27	10 30	6·2
Sept. 7	8 20	6·4	29	11 5	5·9
16	7 40	6·4	Nov. 1	10 8	5·7
17	8 15	6·1	13	6 15	6·1
18	7 45	5·75	14	7 30	6·5
18	10 55	5·65	27	7 10	5·8
19	8 20	5·7	Dec. 4	7 10	5·8
22	9 20	6·1	7	6 40	6·2
23	9 15	6·1	9	9 20	6·1
28	11 5	5·75	10	6 45	6·05
29	7 55	5·65	11	7 25	5·7
30	8 55	5·95	13	5 40	5·8
Oct. 8	7 45	6·1	16	7 5	6·3
9	8 20	6·0	17	6 8	6·3
12	9 20	6·2	19	7 15	5·75
21	7 37	5·9	20	5 25	5·65
23	10 15	5·7	21	5 58	5·7
25	7 18	6·0	27	5 35	5·9

A maximum probably occurred during the night of December 20. This corresponds to epoch No. 480, reckoning from an assumed maximum observed by me 1876, December 14.

Introduction to a Catalogue of the Mean Colours of 758 *Stars; with Appendix, containing the Colours of* 26 *Southern Stars.* By W. S. Franks.

The Catalogue of Star Colours presented to the Society * differs somewhat from either of its predecessors. The first catalogue, undertaken at the suggestion of the late Rev. T. W. Webb (*Monthly Notices*, June 1878), was intended to give an approximate idea of the colours of all the naked-eye stars visible in these latitudes, as seen with a 5-inch refractor. It contained 3890 stars, the southern limit in Declination being −25°. The time occupied—about ten months—in the survey of so many stars was necessarily too short to admit of other than single observations of each object, and the list so made was regarded then more as an experimental opening of a new field than as a work for future reference. In 1884, however, the greater portion

* Deposited in the Library.

of these observations was included (in an abbreviated notation) by Professor Pickering in his "Meridian Photometry," published as vol. xiv. part i. of the *Annals of Harvard College Observatory*. About this time the idea occurred to me that as I had worked for some years exclusively with *reflecting* telescopes, whilst the aforesaid colour estimates were made with a *refractor*, it might be worth while to repeat some of the observations, to ascertain how far the results would be affected by the kind of instrument used. Accordingly the colours of some 1730 of the brighter stars were re-examined, between October 1884 and March 1886, two Newtonian reflectors, of 11¼ inches and 5¼ inches aperture, being employed for the purpose. The smaller instrument was reserved for circumpolar objects, which were not accessible to the 11¼-inch on account of its peculiar mounting. The results arrived at were embodied in the second catalogue, the introduction to which appeared in the *Monthly Notices* for April 1886. The opinion is therein expressed that no appreciable difference exists between the colour results yielded by a reflector and a refractor, but that a great difference of aperture does exert a modifying effect. In both of these catalogues the colours of the stars were given according to the old conventional style, in which the tints of flowers, fruit, and precious stones played a prominent part. But the need for something more definite and systematic than these terrestrial analogies had long been felt, and therefore I attempted the measure of reform described in *Monthly Notices* for March 1887. After subjecting the new system of nomenclature to practical tests by myself and other observers, I determined to make a fresh survey of the colours of some of the brighter stars on this plan, in order to show its adaptability to the required purpose. The selection was guided by Proctor's *Small Star Atlas*, and only such stars retained as were designated by Greek letters; the total number being 758, between the north pole and 25° S. Declination. Three telescopes, all reflectors, were employed in the work, which was begun on December 18, 1886, and completed by October 11, 1887. The apertures and powers used were as follows:—(1) 11¼-inch Calver, 80 inches focus; eyepieces 90 and 200 Kellner; the observations with this instrument are entered in *black* ink. (2) 5¼-inch Calver, 40 inches focus, eyepieces 45 Kellner and 120 Huyghenian; observations written in *red* ink. (3) 8½-inch With, 63 inches focus, eyepieces 70 and 140 Kellner; observations in *violet* ink. Higher powers were occasionally used in the scrutiny of double stars. Telescopes 1 and 2 passed out of my possession during the progress of the work, the 8½-inch With being exclusively devoted to it from May 8, 1887, to its completion. Finding that I could observe stars much lower than −25°, on or near the meridian, I made a working list of some twenty-six that were above 4 mag., and situated in the zone from −25° to −34°. These are given in the Appendix. It may be thought that colour observations of such low stars cannot possess any value, on account of the great atmospheric

disturbance which usually prevails near the horizon; and this is undoubtedly true in a general sense. But the experience gained by many thousands of colour estimates had taught me to discriminate somewhat between the inherent hue of a star and its accidental surroundings, otherwise I should not have attempted it. Knowing, also, that no previous observations existed of the colours of most of these objects, I thought that even a crude approximation to their tints was better than absolute ignorance of them, and that the observations so made might possibly be of some service as bearing on the question of atmospheric absorption, when compared with others that may be afterwards made at some southern station.

The catalogue itself needs but little explanation. The work was originally divided into four zones—circumpolar, northern, equatorial, and southern—for convenience in observing, and it has not been thought worth while to disturb this arrangement. The constellations in each zone, as well as the stars in each constellation, being in order of Right Ascension, there can be no difficulty in identifying any object. Column I. gives the name of the star, according to the authority of the B.A.C.; the mark * indicates that it does not appear in the 1884–86 Catalogue, and †* that it is not included in either the 1877–78 or 1884–86 observations. Column II. has the adopted *mean* colour, deduced from the observations in last column but one; columns III. and IV. the R.A. and Declination for epoch 1880 (these are merely approximate, but sufficient for identification); and column V. the photometric magnitude of the star, derived from the Harvard published results. The next column contains the observed colour on three different occasions; and the last column supplies the date of each observation, together with such remarks as are incidental to the object. As to the system of nomenclature used, the coloured chart will give a fair idea of it, though it is not pretended that its execution is artistic, or that the tints themselves are in exact accordance with those of the spectrum on which it is based. The annexed table presents the complete list of symbols, with their equivalents in the ordinary notation. Any further particulars can be ascertained on reference to the paper in the *Monthly Notices* (vol. xlvii. No. 5). The term "bluish purple" (BP) has, however, in the present work been changed to "bluish violet" (BV), as being more in harmony with the general plan of nomenclature.

The Appendix contains the mean colours of twenty-six stars above 4 mag., from $-25°$ to $-34°$, five observations being made of each. Their colours had not, with one or two exceptions, been previously recorded, and the present attempt only professes to be an approximation to their real tints. It is hoped that some southern observer will re-examine them, and give the result of the comparison.

Occultations of Stars during the Total Eclipse of the Moon, 1888, *January* 28, *observed at the Armagh Observatory.* By J. L. E. Dreyer, Ph.D.

I observed the eclipse with the 10-inch refractor, which is erected 120 feet south of the centre of the transit room. Time determinations were made with the mural-circle immediately before and during the eclipse, and the clock in the dome was repeatedly compared with that in the transit room by electric signals. The sky was cloudless but somewhat foggy. A number of stars not given in the following list were watched either at disappearance or reappearance, but the times could not be observed accurately in consequence of the brightness of the limb. For nearly half an hour after the commencement of the total phase the preceding limb of the Moon was still nearly as bright as before totality, and a similar brightness of the following limb occurred before the end of the total phase. About the middle of the eclipse the Moon appeared to the naked eye as a fairly bright disc with a dark isosceles triangle inscribed in it, having the base to the north.

In reducing the observed times to Greenwich Mean Time the longitude $0^h\ 26^m\ 35^s{\cdot}5$ was used. The latitude of the dome is assumed $= 54°\ 21'\ 11''{\cdot}5$; it is 210 feet above mean sea level.

Star's No.	Phenom.	Loc. Sid. T.	G.M.T.	Remarks.
		h m s	h m s	
164	Disapp.	6 36 14·3	10 32 19·4	Fair.
165	Disapp.	6 37 18·7	10 33 23·6	* very faint.
198	Disapp.	7 13 30·9	11 9 29·9	Fair.
209	Disapp.	7 24 6·0	11 20 3·2	Difficult.
210	Disapp.	7 24 57·0	11 20 54·0	—
201	Disapp.	7 28 24·3	11 24 20·8	Good.
164	Reapp.	7 49 9·2	11 45 2·3	Good.
236	Disapp.	7 56 2·0	11 51 54·0	* very faint.
201	Reapp.	8 8 47·1	12 4 37·0	—

The Total Lunar Eclipse of 1888, *January* 28, *observed at the Dunsink Observatory.* By A. A. Rambaut.

(*Communicated by Sir R. S. Ball.*)

On the night of January 28 this observatory was specially favoured in point of weather. Although during the afternoon the clouds looked very threatening, shortly after the Moon rose the sky cleared, and remained perfectly unclouded for the rest of the night.

The instrument employed was the "South" equatorial of $11\frac{3}{4}$ inches aperture, carrying a power of 177, and the dome was

connected with the chronograph described in the Sixth Part of our publications, which has just been distributed, and which contains a copy of one of our chronograph sheets.

It is, of course, very much more difficult to determine the instant at which an occultation occurs than the time of transit across a wire when it is estimated with the eye and ear from a clock or chronometer, especially if the phenomenon takes place sooner than expected, but with the chronograph this difficulty, I believe, almost wholly disappears.

In observing a transit with the meridian circle it is my habit (I do not know what that of others may be) to make no motion until the star appears exactly bisected by the wire; that is to say, I do not attempt to make the signal and the transit exactly simultaneous, though it might be possible to do so when the star is in view the whole time. There is thus a constant difference between the time of transit and that at which the signal is sent, which in the determination of star places is of course eliminated.

In the case of an occultation the signal must be sent a little too late by an amount depending on the personal equation of the observer. But I believe that in my case the two signals are directly comparable, and I should be inclined to give as much weight to the time of a good observation in the list which is given below, as to the time of transit at a single wire.

The list which we received from Professor Otto Struve contained 73 occultations—disappearances and reappearances—but as the intervals between some of them appeared too short, the number was reduced to 63 before the date of the eclipse. I took the precaution of checking all Professor Struve's results by means of the formulæ given in his circular and the figures he sent us along with the list.

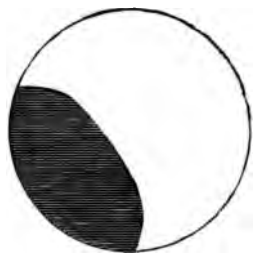
In the case of 141 the corrections, amounting to $0^m.7$ and $0^m.4$ respectively, were of great use, especially at its reappearance, since without it the occurrence might easily have been missed.

No trace of the penumbra was noticeable to the naked eye before $9^h\ 10^m$ G.M.T., but on looking through the telescope at that hour it was observed that more than half the disc was slightly obscured. By $9^h\ 23^m$ the whole surface had become more or less shaded, and appeared of a dull sandy colour, except the western limb, which was still of a silvery hue.

At $9^h\ 31^m$ the first trace of the shadow was noticed. At about $9^h\ 35^m$ the limb assumed the colour of copper, whereas the edge of the shadow appeared almost black. Aristarchus, which was then in the shadow, appeared considerably brighter than the surrounding region.

At $9^h\ 55^m$ the obscured portion became visible to the naked eye, the limb appearing less shaded than the edge of the shadow, the disc having almost the effect of being bounded by a bright line. At this hour, when the magnitude of the eclipse was about 0·4, the shadow appeared to the naked eye somewhat the shape

shown in the diagram, but the telescope showed no trace of irregularity in outline.



The following is a list of the occultations observed during the total phase of the eclipse :—

Occultations of Stars observed during the Total Lunar Eclipse of 1888, *January* 28.

"South" refractor of $11\frac{3}{4}$ inches. Power, 177.

Star.	Dunsink Sidereal Time. Disappearance.	Dunsink Sidereal Time. Reappearance.	Greenwich Mean Time. Disappearance.	Greenwich Mean Time. Reappearance.
	h m s	h m s	h m s	h m s
153	6 31 41·64	7 39 13·37	10 26 33·3	11 33 53·9
157	6 34 37·38	7 28 47·61	10 29 28·5	11 23 29·9
164	6 37 22·55	7 50 37·75	10 32 13·2	11 45 16·5
166	6 37 31·78	7 47 51·35	10 32 22·5	11 42 30·5
165	6 38 34·98	7 51 11·23	10 33 25·5	11 45 49·8
141	6 44 54·19	7 9 6·35	10 39 43·7	11 3 51·9
136	—	6 49 14·67	—	10 44 3·4
180	6 50 32·58	7 59 49·05	10 45 21·1	11 54 26·2
172	6 53 28·17	7 52 21·14	10 48 16·2	11 46 59·6
181	7 1 30·85	7 53 14·96	10 56 17·6	11 47 53·2
128	—	7 3 21·18	—	10 58 7·6
198	7 14 34·85	—	11 9 19·5	—
194	7 18 31·05	8 4 34·11	11 13 15·0	11 59 10·5
142	—	7 22 0·36	—	11 16 43·8
148	—	7 24 59·85	—	11 19 42·8
190	7 27 0·63	8 9 23·47	11 21 43·2	12 3 59·1
155	—	7 32 39·04	—	11 27 20·7
150	—	7 35 34·65	—	11 30 15·8
216	7 40 33·32	—	11 35 13·7	—
225	7 42 48·92	—	11 37 28·9	—
224	7 43 51·24	—	11 38 31·1	—
236	7 56 36·03	—	11 51 13·8	—
201	—	6·22	—	12 7 41·2
247	8 15 30·04	—	12 10 4·7	—

Remarks.

	Disappearance.	Reappearance.
153	—	Good.
157	Very well seen.	Good.
164	Good.	Good.
166	Good.	Good.
165	Good.	Good.
141	Very bad; limb still very bright.	Perhaps half a second late.
136	—	Perhaps a quarter of a second late.
180	Beautiful.	Subtract half a second.
172	Difficult.	—
181	Good.	Perhaps a few tenths of a second late.
128	—	Fair.
198	Beautiful. Instantaneous.	—
194	Good.	Good.
142	—	Fair.
148	—	Excellent.
190	Seemed to be extinguished momentarily several seconds before final disappearance.	Good.
155	—	Clear of limb when first seen and signal sent. Very faint. Observation almost worthless.
150	—	Good.
216	Limb brightening.	—
224	Difficult owing to brightening of limb.	—
236	Projected on the disc a few seconds before final disappearance.	—
201	—	Good, although limb very bright.
247	Appeared in contact with limb 2s before final disappearance.	—

At $11^h\ 6^m\ 25^s$ a meteor crossed the disc of the Moon slightly to the south of Plato, the position-angle of its path being about 250°.

The end of the total phase occurred between the times given for the occultations of 201 and 247. I find in my note-book opposite No. 201, "Bright limb reappears," and opposite No. 247 "Totality distinctly over." The mean of the two would give $12^h\ 9^m$.

As the shadow passed off the Moon nothing of importance was noticed. No irregularity was observed in the outline of the shadow which might not be accounted for by the colour of the surface where it fell. Where the edge crossed the grey plains, the darkening of the surface in immediate proximity to the edge of the shadow had the effect of making the latter appear to project a little beyond the regular curve which bounded it, but as the shadow passed on the protuberance disappeared, or reappeared in another place, according to the nature of the surface where it happened to fall. This effect was most noticeable when the shadow crossed the Mare Serenitatis and the Mare Tranquillitatis.

The last contact with the shadow took place at $13^h\ 10^m$.

These times, though of course liable to error on account of the diffused edge of the shadow, are at least free from bias. I was observing with a chronometer which recorded sidereal time, and I had no idea of the correction necessary to reduce it to G.M.T. I therefore give the figures for what they are worth.

Dunsink: 1888, *February* 3.

Observations of Stars made at the Glasgow Observatory in connection with the Total Eclipse of the Moon of 1888, *January* 28.

(*Communicated by Professor R. Grant, F.R.S.*)

The eclipse was observed under favourable circumstances as regards the weather. The observations of disappearance and reappearance were made with the 9-inch equatorial. The observer was Mr. John McKinnell.

No. of Star.	Mag.	Disappearance. G.M.T.	Reappearance. G.M.T.
		h m s	h m s
153	10	10 28 49·25	...
164	8	10 35 56·99	11 48 7·64
165	9·5	10 36 49·75	...
180	9·5	10 51 12·32	11 54 51·05
126	9·5	...	10 59 45·89
148	10	...	11 19 30·64
157	9·5	...	11 21 15·14
201	8·5	11 33 44·81	12 1 10·90
225	10	11 40 35·48	...
166	9·5	...	11 43 25·15

The Moon during total obscuration presented a copper-coloured aspect the hue of which was more pronounced towards the limbs.

The Observatory, Glasgow:
1888, *March* 7.

Occultations of Stars observed at Liverpool Observatory, Bidston, Birkenhead, during the Total Eclipse of the Moon, 1888, *January* 28. By John Hartnup.

The following observations were made with the equatorial, which is provided with an object-glass by Merz, of 8·5 inches aperture. Passing clouds prevented the observation of some of the stars, but the chief difficulty was the brightness of the Moon

when totally eclipsed. This was so great that with the means at my disposal I found it impossible to observe the occultations of the fainter stars in the Pulkowa list.

The instants of disappearance and reappearance were recorded by means of a Bond's spring-governor chronograph, which records automatically every two seconds the time shown by the sidereal standard. The error of the latter was determined on the same evening by a series of transit observations recorded in a similar manner.

As seen from this observatory the total eclipse of the Moon of 1884, October 4, was much darker than that of 1888, January 28.

No. in Pulkowa List.	Mag.	Phenomenon.	Time by Sidereal Standard.	Local Sidereal Time.	Greenwich Mean Time of Observation.	
			h m s	h m s	h m s	
153	10	Disappearance	6 49 1·2	6 49 51·97	10 31 38·83	(*a*)
157	9·4	„	6 53 8·0	6 53 58·77	10 35 44·95	
164	8·0	„	6 53 35·8	6 54 26·57	10 36 12·67	
166	9·5	„	6 53 46·7	6 54 37·47	10 36 23·55	
165	9·4	„	6 54 49·2	6 55 39·97	10 37 25·87	
180	9·5	„	7 6 55·4	7 7 46·18	10 49 30·10	(*b*)
190?	11	„	7 42 23·4	7 43 14·19	11 24 52·30	(*c*)
157	9·4	Reappearance	7 44 36·8	7 45 27·59	11 27 5·34	
166	9·5	„	8 4 23·6	8 5 14·40	11 46 48·91	
164	8·0	„	8 7 30·4	8 8 21·20	11 49 55·20	
165	9·4	„	8 8 4·0	8 8 54·80	11 50 28·70	(*d*)

Notes.

(*a*) Star faint. (*b*) Disappeared at $7^h\ 6^m\ 49^s{\cdot}6$, but reappeared about two seconds later, and finally disappeared at $55^s{\cdot}4$. (*c*) Star very faint; observation doubtful. (*d*) About one second late.

Power used, 90. The longitude $12^m\ 17^s{\cdot}15$ W. has been used in converting Bidston mean solar time into Greenwich mean solar time.

Observations of Occultations of Stars made at the Radcliffe Observatory, Oxford, during the Total Lunar Eclipse of 1888, *January* 28.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following occultations were observed under rather unfavourable atmospheric circumstances, the sky becoming hazy and cloudy.

No. in Palkowa List.	Mag. from List.	Phenom.	Time noted. h m s	G.M.T. of Observation. h m s	Observer.	Ref. to Notes.
...	(10)	Disapp.	6 41 21·2	10 15 50·3	W.	(*a*)
148	10	,,	6 47 11·3	10 21 39·4	W.	(*b*)
157	9·4	,,	6 57 53·8	10 32 20·2	W.	
		,,	6 58 42·	20·5	R.	(*c*)
		,,	10 32 41·	18·4	F. B.	
164	8·0	,,	7 3 44·3	10 38 9·7	W.	
		,,	7 4 32·2	9·7	R.	(*d*)
		,,	10 38 31·8	9·2	F. B.	
165	9·4	,,	7 6 (0·)	10 39 (37·)	R.	(*e*)
		,,	10 39 33·	10 39 10·4	F. B.	
180	9·5	,,	7 15 55·8	10 50 19·2	W.	
		,,	7 16 44·0	19·5	R.	(*f*)
		,,	10 50 42·3	19·6	F. B.	(*g*)
126	9·5	Reapp.	7 27 33·5	11 1 55·0	W.	
		,,	7 28 16·5	50·1	R.	(*h*)
		,,	11 2 12·5	49·8	F. B.	(*i*)
201	8·7	Disapp.	7 51 46·	11 26 3·6	W.	(*j*)
		,,	7 52 33·	2·7	R.	(*k*)
		,,	11 26 23·8	1·1	F. B.	(*l*)
157	9·4	Reapp.	11 32 45·	11 32 22·2	F. B.	(*m*)

Observer.		Aperture. in.	Power used.
W.	Mr. W. Wickham, Barclay Equatorial .	10	85
R.	,, W. H. Robinson, Heliometer . .	7·5	80
F. B.	,, F. A. Bellamy, 10-foot Telescope .	7	90

Notes.

(*a*) and (*b*) Faint, cloudy. Both stars about the same angle and magnitude. (*c*) Doubtful to 2ˢ. Faded gradually. (*d*), (*f*), (*g*), and (*i*) Good observations. (*e*) Exceedingly faint. Observation very doubtful. May be 10ˢ in error. Cloudy. (*h*) Fairly good. Reappeared instantaneously. At $11^h\ 1^m\ 30^s \pm$ a meteor of about the 7th star magnitude flashed across Moon from 225° (± 5°) through 75° (± 20°) from North Point. (*i*) Whilst watching for reappearance, saw the meteor referred to by Mr. Robinson. (*j*) A slow disappearance. (*k*) Faint; difficult. (*l*) and (*m*) Hazy cloud.

Radcliffe Observatory, Oxford:
1888, *January* 30.

Observations of Stars Occulted by the Moon during the Eclipse of 1888, January 28, at the University Observatory, Oxford. Made under the direction of Professor C. Pritchard, D.D., F.R.S.

All due preparations were made for observing the occultations; but the state of the sky was so fitful, and in general so hazy, that very few phenomena could be observed at all, and of those that were attempted probably none is of any value—not even excepting No. 164, where the times of disappearance recorded by the two observers are identical, and the reappearance of No. 136, where the recorded times are fairly close.

Four photographs of the Moon, taken with a 15-inch mirror, were secured before totality, but they possessed the same abortive characteristics as those presented by the star occultations, and from the same causes.

The intention was to photograph the district containing the occultable stars, but up to the present time the sky has presented no favourable opportunity.

Phase	Immersion.		Emersion.	
Instrument	Grubb Refr.	De la Rue Refl.	Grubb Refr.	De la Rue Refl.
Aperture	12½ inches.	13 inches.	12½ inches.	13 inches.
Power	120	80	120	80
Observer	Jenkins	Plummer	Jenkins	Plummer
G.M.T.	h m s	h m s	h m s	h m s
No. 157*	10 31 48·3			
164	10 38 9·1	10 38 9·1		
180	...	10 50 20·5		
136	...	...	10 56 1·2	10 55 59·9
126	...	...	11 1 53·4	11 1 55·4
128	...	...	...	11 4 53·7
*	11 13 58·9			
198	...	11 15 39·6		
201	11 26 2·4	11 26 3·5		

University Observatory, Oxford:
1888, *March* 8.

* Numbers as given in Dr. Döllen's list, dated Pulkova, Dec. 18, 1887.

Total Eclipse of the Moon, 1888, *January* 28.

By the Rev. S. J. Perry, D.Sc., F.R.S.

The long duration of this eclipse, and the pains taken by Professor Döllen in calculating the positions of the stars to be occulted at Stonyhurst during totality, made me give special attention to the preliminary observations for this eclipse. Some of the star places were recalculated by the Rev. W. Crofton, as Professor Struve in his circular to the observatories had requested that this should be done for greater security, and the results proved that the graphical method adopted by Professor Döllen was sufficiently accurate. A careful map was also drawn of all the stars to be occulted, and this was compared with the charts of Chacornac and Argelander in order to identify as many stars as possible beforehand. A $5\frac{1}{2}$-inch achromatic of Alvan Clark, which gives most perfect definition, was set apart for the occultations, and was supplemented by a 4-inch equatorial of Jones. The 8-inch instrument of Simms was reserved for a spectroscopic examination of the light of the eclipsed Moon, and the spectroscope used on this equatorial was so constructed by Hilger that one or two prisms of 30° can be used at will, six sets of prisms of aluminium, quartz, calcite, dense flint, white flint, and crown glass being adapted to the same mounting. A series of observations was made with the different prisms during the week that preceded the eclipse, measurements of the lines in the spectrum of the clouds and also of the lunar crescent were taken, and the spectroscope was found to work very satisfactorily. Two aluminium prisms gave altogether the best results, as the lunar spectrum was strong, and the fine lines distinct throughout. A single prism of aluminium glass, or of white flint, gave equally good definition, though the lines were somewhat clearer in the violet with the aluminium, and in the rest of the spectrum with the flint. The calcite was at least as good as either of the other prisms in the red, and was fair in the violet, but much inferior in the remainder of the spectrum. The dense flint and crown gave the lines less distinctly; but with one, or with two, quartz prisms the details were seen almost as well as with the aluminium. I am dwelling rather longer on these preliminary observations than might perhaps be deemed necessary, but I am doing so advisedly, as the trustworthiness of the results obtained during the eclipse must depend mainly on the fitness of the spectroscope for the object proposed.

Early on the evening of the eclipse the sky was all that could be desired, and the penumbra was very visible on the Moon at $8^h\ 48^m$. A series of readings of the principal lines in the lunar spectrum was then taken, the two aluminium prisms being used, and giving a very extended spectrum. During these measures cirrus clouds were thickening, and a brilliant double halo formed round the Moon two orange rings, of about 12° and 16° in

diameter, enclosing a space of a greenish-blue tint. At $9^h\ 25^m$ the penumbra at the eastern limb had become very dark, and at $9^h\ 29^m$ the shadow gave the limb the appearance of being flattened, which was probably the effect of the first contact of the umbra. At $10^h\ 5^m$ nearly the whole of the limb of the partially eclipsed Moon, and also great part of the shaded surface, was clearly visible in spite of cirrus clouds. The outline of the umbra was not very regular, a long depression appearing near the centre with a considerable elevation north of the centre, and a less striking one near the south point. At $10^h\ 12^m$ the eclipsed portion of the Moon was becoming more distinct, its colour being a brick red, but almost orange in the brighter parts. Five minutes before totality thin clouds were still around the Moon. The beginning of totality was noted at $10^h\ 30^m\ 21^s{\cdot}9$ G.M.T. About five minutes after totality commenced the stars were shining brightly in every direction, and the fainter ones were visible in the telescope, showing that the clouds had entirely disappeared. A curious wedge-shaped and very dark shade was observed on the lunar surface, and its form cannot be accounted for by any of the known features of the Moon.

The eclipsed Moon, which was very distinct, although its general appearance was that of a bright object seen through a fog, was being kept by the driving clock on the slit of the spectroscope, lest any uncertainty as to its exact position might arise—a precaution not always unnecessary in previous eclipses. The viewing telescope of the spectroscope had been most carefully focussed on the green part of the spectrum, with the pointer of the micrometer fixed on the line corresponding to 1474 K. I chose this position because I thought that, if any bright lines from the outer corona were reflected by the lunar surface, this well known coronal line would be the most conspicuous. Nothing was altered, no screw touched, and I felt sure that the two aluminium prisms were under the best conditions for showing the true spectrum of the eclipsed Moon. I scarcely expected to see so much light through the spectroscope with so narrow a slit, but I looked in vain for any sign of bright or dark lines, and my assistant, Mr. W. McKeon, whose eye is exceedingly well trained, was equally unsuccessful in detecting lines. The spectrum, extending from the red to somewhat beyond F, was of a rather indistinct yellowish green throughout. A wider slit increased the amount of light, and showed the red end of the spectrum fairly well, but the violet was completely cut off, as well as most of the blue. No appearance of lines, or even of increased intensity of light, at any point of the spectrum could be noted.

At $10^h\ 40^m\ 17^s$ the west limb to a considerable width was much brighter than the rest of the surface, and interfered very much with the faint stars whose occultations were being observed through the $5\frac{1}{2}$ and 4-inch achromatics.

The triangular, or wedge-shaped, patch of shadow had now become much darker than the remainder of the surface; but at $10^h\ 54^m\ 30^s$ this dark patch was already more diffused.

One prism of aluminium glass, and then one of quartz, and lastly one of white flint, were now tried in the spectroscope, but with no other result than that obtained with the two prisms of aluminium; although the quartz gave a larger quantity of light, especially at the red end of the spectrum, whilst with the flint prism the red was scarcely visible. As we had not the advantage of focussing on the bright Moon before each of these changes, the observation with the two prisms of aluminium can alone be considered perfectly satisfactory, although the observations with the single prisms afford some confirmation of the previous result. The spectrum of the eclipsed Moon was, I think, quite bright enough to have shown dark lines had the ordinary solar lines been present; and I hardly imagine that the diminution of light, in passing from the spectrum of the bright to that of the eclipsed Moon, was sufficient to account for the total absence of so much of the blue end of the spectrum. I hope on July 22 of this year again to examine the spectrum of the eclipsed Moon with the same instrument, but substituting quartz lenses, in place of ordinary achromatics, for the collimator and viewing telescope; and then with quartz prisms the violet end, if not greatly absorbed, will scarcely escape detection.

At $11^h\ 10^m$ the surface of the Moon was throughout of a more uniform tint, the seas, however, being of a somewhat darker red than the other portions; the only exceptional feature was a not very conspicuous brightening of the southern limb. The irregular dark patch mentioned above had entirely vanished. At $11^h\ 27^m$ the illumination of the limb was passing round to the eastern side. At midnight the Moon's edge was rapidly brightening, and at $12^h\ 7^m\ 13^s$ the end of totality was noted. Two small bright projections, about 8° apart on the limb, were very striking in the 4-inch finder; they were near the point of reappearance.

The following is a list of the observed occultations, the stars being numbered according to the printed list sent by Professor O. Struve to the observatories of Europe.

Star.	Greenwich Mean Time. Disappearance.	Reappearance.	Diam. of O.G.	Power.	Observer.	Remarks.
	h m s	h m s				
157	10 35 8·1	—	5½	46	W. J. C.	Passing clouds.
164	10 37 6·5	11 50 44·1	4	44	A. C.	
„	10 37 6·7	11 50 44·1	5½	46	W. J. C.	
136	—	10 46 9·7	„	„	„	
180	10 50 51·3	—	„	„	„	
„	—	11 59 2·6	„	„	W. C.	
126	—	11 1 33·8	„	„	W. J. C.	
209	11 25 48·4	—	„	„	W. C.	Very faint.
201	11 29 16·1	12 10 14·4	4	44	A. C.	
„	11 29 16·4	12 10 14·2	5½	46	W. C.	
166	—	11 47 19·1	„	„	„	
165	—	11 51 29·8	„	„	„	
236	11 55 40·4	—	8	43·5	S. J. P.	Last seen.

The initials W. J. C., A. C., W. C., and S. J. P., are those of the observers William Crofton, Aloysius Cortie, William Carlisle, and Stephen Joseph Perry.

Stonyhurst Observatory:
1888, *February* 16.

Occultations observed at Harrow during the Total Eclipse of the Moon, 1888, *January* 28. By G. L. Tupman.

Every precaution was taken to ensure success on this occasion, but fleecy clouds and haze and the unexpected brightness of the Moon rendered the smaller stars quite invisible.

General Tennant very kindly came over and observed with the 18-inch mirror, using the chronograph to register the times. He says:—

"Very soon after totality commenced the sky near the Moon was clouded, and from that time, although the Moon's limb was generally visible, stars were rarely so. From what was seen, it was evident that the Moon was very bright and white in colour, even on the limb near the centre of the shadow (the other limb was much brighter), and that the smaller stars could not have been seen in contact with the limb. Indeed, at the disappearance of No. 166 and No. 164 each was thought to be gone some 3^s before the times noted, but a re-examination showed that they were still on the limb though hardly distinguishable."

I looked at the Moon for a minute or two, with the large reflector, half an hour after the commencement of totality. Not a star was to be seen near it. I do not agree with General Tennant that the Moon was white; to me it was very red, although less red in the telescope than with the unaided eye.

The following are the times as read from the chronograph fillet; they should be diminished $0^s.3$ or $0^s.4$:—

Star.	Clock.	Local Sidereal Time.	Greenwich Mean Time.
	h m s	h m s	h m s
157	Im. 7 3 17·2	7 2 26·65	10 33 15·9
166	Im. 7 8 18·5	7 7 27·95	10 38 16·4
164	Im. 7 9 25·2	7 8 34·65	10 39 22·9
164	Em. 8 24 0·0	8 23 9·45	11 53 45·5
180	Em. 8 34 23·3	8 33 32·75	12 3 7·1*

* This was seen as a bright speck on the limb at this moment; but the limb was only seen clearly for a few seconds, and before the observation could be verified it was dulled by the mist.—J. F. T.

I observed for local time the same evening with the meridian circle :—

	Clock Correction.
	s
5 Ursæ Min., S.P. (one wire only)	−50·25
δ Ceti	−50·52
θ Persei	−50·41
δ Geminorum	−50·60
Daily rate of clock	s −0·58

The coordinates of the observatory are : Lat. 51° 34′ 47″·4 N.; Long. (W. of Greenwich) 1ᵐ 19ˢ·85; height above mean sea level, 220 feet.

Note by General Tennant.—The peculiarity (for I seem to have been singular) in my estimation of the colour of the Moon during eclipse is probably due to the eye. In vol. xxix. p. 106, of the *Notices*, will be found a note that red stars did not produce on my eye the impression of marked colour. This especially refers to the right eye used in these observations.

An Improved Centering Tube for Reflecting Telescopes.

By Edward Crossley, M.P.

In the *Monthly Notices* for March 1887 I gave a description of a new centering tube for reflecting telescopes. I have since much improved its construction so as to make it more easily used and more accurate.

It consists of a tube A B C D, figs. 1, 2, 10 inches long, $2\frac{5}{8}$ inches in diameter, with an open elbow E F. Opposite this elbow is placed a plane reflector, A G, perforated at H. A surface of bright tin answers well. In the centre at A B is the pin hole I. At C D is placed a perforated disc, J, 1 inch in diameter, with $\frac{1}{4}$-inch hole, attached to a rim by four arms placed edgewise; the rim slides into the tube. It is used in the following manner :—

The tube is placed in the eyepiece end or holder of the telescope, to which it is a nice fit; and looking through I H and the

whole aperture C D without removing J, the eye end is adjusted so that the flat appears central. A disc of white paper half the diameter of the tube is gummed to the centre of the face of the large mirror. The flat is then adjusted so as to show the disc by reflection central in the aperture of J.

These operations can be performed by daylight. The disc is most easily seen by side light down the tube.

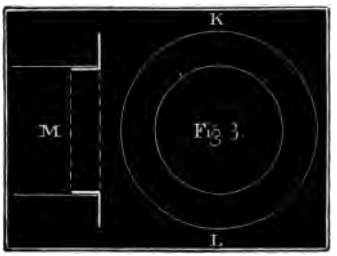


Fig 3.

In order that the last operation can also be performed by daylight a ring cap or collar, K L of section M, is placed in the tube at C D, and the plane annular face of this collar towards the flat is painted white.

The daylight which illuminates the disc on the large mirror will also illuminate the white ring, and the large mirror can now be adjusted so that the white ring shall appear by reflection exactly central with the disc. The adjustment of the telescope is now complete.

The whole of these adjustments can also be made in the same order by holding a bull's-eye lantern with the lens in the elbow E F. The elbow shields the eye from the light. The mirror A G throws ample light through the aperture C D without removing J, so that an image of the aperture is reflected back by the large mirror and the flat so as to appear like a halo surrounding the disc (like an annular eclipse of the sun) in the centre of the aperture J, when the flat and the large mirror have been adjusted in the same order as before.

The advantages of this centering tube are that it can be used night or day in any position of the telescope by simply putting it in place of the eyepiece, and accurate centering is at once obtained.

Telegraphic Determination of the Longitude of Haiphong.

By Dr. W. Doberck.

(*Communicated by the Astronomer Royal.*)

The determination of the longitude of Haiphong was undertaken at the proposal of M. La Porte, Chef de la Mission Hydrographique du Tonkin, and effected through the cable of the Eastern Extension, Australasia and China Telegraph Company, which was placed at our disposal for a short time on three consecutive evenings at the request of the Résident-Général du Tonkin. The telegraphists at both stations assisted us with the great courtesy always experienced from that Company in matters of public interest by scientific men in different parts of the world. Unfortunately, owing to the approaching departure from Haiphong of M. La Porte, there was not much time to make detailed arrangements beforehand.

Signals were exchanged on the 5th, 6th, and 7th April, 1887. The weather was clear at both stations, and transit observations of a sufficient number of stars were obtained each night both in Haiphong and in Hongkong. The small observatory in Haiphong is placed beside the Post Office "à 310 m. dans l'ouest du point marqué Pagode de l'Observatoire sur le plan français 3506 (Plan des Environs de Haiphong et de Quang-Yen)." The masonry pier on which the transit instrument is placed was constructed more than a year ago. The transits were observed by M. La Porte with a sidereal chronometer, which was, on the two first nights, carried down to the telegraph office for use in exchanging signals, being compared before and after this transport with a chronometer that remained in the observatory. On the last night the sidereal chronometer remained in the observatory, and was compared with a mean-time chronometer by aid of which the signals were exchanged.

The observations in Hongkong were made with the transit instrument and the sidereal standard clock. Mr. F. G. Figg made the observations and comparisons on the 6th, and I myself observed and compared on the 5th and 7th. The standard clock was compared with two mean-time chronometers which were carried across the harbour in a steam launch. After our return the chronometers were again compared. Inter-comparisons in the telegraph office proved the regularity of their rate in the meantime. They were used alternately in the exchange of the signals.

The signals were made and observed as follows:—The attention of the observer at the other station was called by a number of taps, and half a minute later eight or nine signals were given at every ten seconds on the chronometer by depressing the key. After changing the observer and chronometer in Hongkong attention was again called and another series sent. The signals

consisted in deflections of the ink-writer on Sir W. Thomson's Patent Siphon Recorder, and were observed by eye and ear with the chronometers by M. La Porte, in Haiphong, or by the two observers in Hongkong. Subsequently the Haiphong and Hongkong Mean Times of the mean of each series of signals were obtained as explained above, and they are exhibited in the following table.

1887, *April* 5.

From	To	Observer.		H. K. M.T.	Hph. M.T.	Difference.	Longitude.
		H.K.	Hph.	h m s	h m s	m s	m s
H. K.	Hph.	D.	P.	8 47 14·27	8 17 16·66	29 57·61	29 57·95
„	„	F.	„	8 49 21·70	8 19 24·08	57·62	57·96
Hph.	H. K.	D.	„	8 53 45·48	8 23 47·10	58·38	58·04
„	„	F.	„	8 53 45·67	„	58·57	58·23
„	„	„	„	9 0 14·24	8 30 15·99	58·25	57·91
„	„	D.	„	9 0 14·24	„	58·25	57·91
„	„	F.	„	9 4 23·50	8 34 25·32	58·18	57·84
„	„	D.	„	9 4 23·65	„	58·33	57·99
„	„	F.	„	9 11 12·40	8 41 14·18	58·22	57·88
„	„	D.	„	9 11 12·43	„	58·25	57·91
H. K.	Hph.	„	„	9 14 51·70	8 44 53·98	57·72	58·06
„	„	F.	„	9 18 54·44	8 48 56·88	57·56	57·90

1887, *April* 6.

H. K.	Hph.	D.	„	8 44 20·84	8 14 23·36	57·48	57·71
„	„	F.	„	8 46 20·64	8 16 23·14	57·50	57·72
Hph.	H. K.	D.	„	8 55 1·76	8 25 3·82	57·94	57·72
„	„	F.	„	8 55 1·84	„	58·02	57·79
„	„	D.	„	8 56 31·43	8 26 33·58	57·85	57 62
„	„	F.	„	8 56 31·53	„	57·95	57·73

1887, *April* 7.

H. K.	Hph.	D.	„	8 32 7·53	8 2 10·15	57·38	57·66
„	„	F.	„	8 40 0·14	8 10 2·57	57·57	57·85
„	„	D.	„	8 43 41·14	8 13 43·62	57·52	57·80
„	„	F.	„	8 44 37·56	8 14 40·05	57·51	57·79
Hph.	H. K.	D.	„	8 48 19·56	8 18 21·63	57·93	57·65
„	„	F.	„	8 48 19·68	„	58·05	57·77
„	„	D.	„	8 50 19·65	8 20 21·62	58·03	57·75
„	„	F.	„	8 50 19·85	„	58·23	57·95

Taking the mean of the differences of time obtained by sending the current in either direction, and then subtracting the smaller from the greater, and dividing by two the amount of retardation due to induction owing to the electro-static capacity of the cable—which is all underground or under water, being insulated by gutta-percha, and 498·6 miles in length—we obtain the retardation. It was on the three nights respectively :—$0^s{\cdot}34$, $0^s{\cdot}225$, and $0^s{\cdot}28$, or on an average $0^s{\cdot}282$. After correcting the observed differences of time for retardation, the different values of the observed longitude of Haiphong west of Hongkong, exhibited above, were obtained.

The means of the results obtained by M. La Porte in Haiphong and the two observers in Hongkong are as follows :—

	Observers.		
	P. and D.	P. and F.	Mean.
	m s	m s	m s
1887, April 5	29 57·977	29 57·953	29 57·965
„ 6	·683	·747	·715
„ 7	·715	·840	·778
Mean	29 57·792	29 57·847	29 57·819

The longitude of the transit instrument in the Hongkong Observatory is, according to observations made in 1881 by Lieut.-Commander Green, U.S.N., who connected Hongkong with both Madras and Wladiwostock :—$7^h\ 36^m\ 41^s{\cdot}86$ east of the meridian of the Royal Observatory, Greenwich, therefore the longitude of the transit instrument in Haiphong is :—

$7^h\ 6^m\ 44^s{\cdot}04$ east of Greenwich.

The probable error of the longitude of Hongkong does not appear to be much more than a tenth of a second, and the probable error of the difference being about a twentieth of a second, it follows that the probable error of the longitude of Haiphong is below a fifth of a second.

Hongkong Observatory:
1887, *December* 23.

Ephemeris for Physical Observations of the Moon for the Nine Lunations from April 12 to the end of 1888. By A. Marth.

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Long. of the Earth.	Lat.	Amount.	Direction.
1888.	°	°	°	°	°	°
April 12	282·50	−1·48	−0·24	+6·54	6·54	2·1
13	294·72	1·49	1·52	6·42	6·60	13·3
14	306·95	1·50	2·81	6·02	6·64	24·9
15	319·17	−1·50	−4·07	+5·36	6·73	37·1
16	331·38	1·51	5·26	4·46	6·90	49·6
17	343·59	1·52	6·33	3·35	7·15	62·0
18	355·80	1·52	7·19	2·06	7·48	74·0
19	8·00	1·53	7·77	+0·64	7·80	85·3
20	20·20	1·53	7·99	−0·85	8·03	96·1
21	32·39	1·54	7·76	2·35	8·11	106·9
22	44·57	−1·54	−7·04	−3·75	7·98	118·2
23	56·75	1·55	5·81	4·97	7·65	130·7
24	68·93	1·55	4·12	5·90	7·19	145·2
25	81·20	1·55	−2·09	6·43	6·76	162·1
26	93·27	1·55	+0·12	6·51	6·51	181·1
27	105·44	1·55	2·29	6·13	6·54	200·5
28	117·61	1·54	4·23	5·31	6·79	218·4
29	129·79	−1·54	+5·79	−4·16	7·13	234·2
30	141·97	1·53	6·87	2·78	7·41	247·9
May 1	154·16	1·53	7·45	−1·28	7·56	260·2
2	166·36	1·52	7·57	+0·25	7·57	271·9
3	178·57	1·51	7·28	1·71	7·48	283·3
4	190·78	1·51	6·66	3·05	7·32	294·7
5	203·00	1·50	5·78	4·23	7·16	306·3
6	215·22	−1·49	+4·73	+5·16	6·99	317·6
7	227·45	1·49	3·56	5·91	6·90	329·1
8	239·69	1·48	2·32	6·37	6·77	340·1
9	251·92	1·47	+1·04	6·54	6·62	351·0
10	264·16	1·46	−0·24	6·44	6·44	2·1
11	276·40	1·46	1·51	6·05	6·24	14·0
12	288·64	1·45	2·76	5·40	6·06	27·0
13	300·88	−1·45	−3·94	+4·51	5·98	41·1
14	313·12	1·44	5·04	3·34	6·04	56·4
15	325·35	1·43	6·03	2·13	6·39	70·5

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Long.	Lat.	Amount.	Direction.
1888.	°	°	°	°	°	°
May 16	337·58	1·42	6·82	+0·73	6·86	83·9
17	349·80	1·42	7·37	−0·73	7·41	95·7
18	2·02	1·41	7·61	2·19	7·91	106·1
19	14·23	1·40	7·45	3·58	8·26	115·7
20	26·44	−1·39	−6·86	−4·80	8·36	125·1
21	38·64	1·38	5·80	5·77	8·18	135·0
22	50·83	1·37	4·30	6·40	7·70	146·3
23	63·02	1·36	2·46	6·61	7·05	159·7
24	75·21	1·34	−0·40	6·36	6·37	176·4
25	87·39	1·33	+1·69	5·66	5·90	196·5
26	99·57	1·31	3·61	4·57	5·82	218·3
27	111·76	−1·29	+5·21	−3·19	6·11	238·5
28	123·95	1·27	6·40	−1·64	6·60	255·6
29	136·14	1·26	7·10	+0·03	7·10	270·1
30	148·34	1·24	7·33	1·52	7·48	281·7
31	160·55	1·22	7·13	2·94	7·71	292·5
June 1	172·77	1·20	6·57	4·18	7·79	302·6
2	184·99	1·18	5·73	5·20	7·73	312·3
3	197·21	−1·16	+4·68	+5·96	7·57	322·0
4	209·45	1·14	3·48	6·45	7·32	331·7
5	221·68	1·12	2·22	6·65	7·01	341·7
6	233·92	1·10	+0·93	6·57	6·64	352·0
7	246·17	1·09	−0·33	6·21	6·22	3·0
8	258·42	1·07	1·57	5·58	5·79	15·7
9	270·67	1·05	2·72	4·69	5·42	30·0
10	282·92	−1·04	−3·77	+3·58	5·20	46·4
11	295·17	1·02	4·70	2·30	5·23	63·9
12	307·42	1·00	5·47	+0·88	5·54	80·8
13	319·66	0·98	6·06	−0·60	6·09	95·6
14	331·90	0·97	6·43	2·08	6·75	107·9
15	344·13	0·95	6·52	3·48	7·39	118·1
16	356·36	0·93	6·30	4·72	7·87	127·0
17	8·58	−0·91	−5·74	−5·73	8·08	135·1
18	20·80	0·89	4·82	6·42	8·02	143·3
19	33·01	0·87	3·56	6·73	7·61	152·2
20	45·21	0·84	2·03	6·60	6·91	163·0
21	57·41	0·82	−0·33	6·04	6·05	176·9
22	69·60	0·79	+1·42	5·07	5·26	195·6

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Long.	Geocentric Libration. Lat.	Geocentric Libration. Amount.	Geocentric Libration. Direction.
1888.	°	°	°	°	°	°
June 23	81·79	0·77	3·06	3·76	4·85	219·1
24	93·98	−0·74	+4·48	−2·22	5·00	243·6
25	106·17	0·71	5·56	−0·57	5·59	264·1
26	118·37	0·68	6·25	+1·07	6·34	279·8
27	130·57	0·66	6·53	2·61	7·02	291·8
28	142·77	0·63	6·41	3·96	7·52	301·8
29	154·98	0·60	5·93	5·07	7·80	310·7
30	167·20	0·57	5·15	5·92	7·84	319·1
July 1	179·42	−0·55	+4·15	+6·49	7·70	327·5
2	191·65	0·52	2·98	6·76	7·39	336·3
3	203·88	0·50	1·73	6·74	6·96	345·7
4	216·12	0·47	+0·45	6·43	6·44	356·0
5	228·36	0·45	−0·79	5·84	5·89	7·7
6	240·60	0·43	1·95	4·99	5·36	21·3
7	252·85	0·40	2·98	3·91	4·92	37·3
8	265·10	−0·38	−3·86	+2·63	4·67	55·7
9	277·36	0·36	4·55	+1·21	4·71	75·1
10	289·61	0·33	5·03	−0·30	5·04	93·5
11	301·86	0·31	5·30	1·82	5·60	109·0
12	314·11	0·29	5·32	3·28	6·24	121·6
13	326·36	0·27	5·11	4·57	6·85	131·9
14	338·60	0·24	4·65	5·64	7·30	140·6
15	350·83	−0·22	−3·96	−6·39	7·51	148·3
16	2·05	0·19	3·05	6·78	7·43	155·9
17	15·27	0·16	1·95	6·75	7·03	164·0
18	27·48	0·13	−0·71	6·31	6·35	173·6
19	39·69	0·10	+0·59	5·47	5·50	186·1
20	51·89	0·07	1·88	4·28	4·67	203·7
21	64·08	−0·04	3·08	2·82	4·17	227·5
22	76·27	−0·01	+4·11	−1·20	4·28	253·7
23	88·46	+0·02	4·90	+0·47	4·92	275·4
24	100·65	0·05	5·39	2·07	5·78	291·0
25	112·84	0·08	5·57	3·52	6·59	302·3
26	125·04	0·11	5·42	4·75	7·20	311·3
27	137·24	0·14	4·96	5·71	7·56	319·1
28	149·44	0·17	4·23	6·38	7·64	326·6
29	161·65	+0·20	+3·26	+6·74	7·48	334·3
30	173·87	0·22	2·12	6·80	7·12	342·8

Greenwich Noon.		Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Long. of the Earth.	Lat.	Amount.	Direction.
1888.		°	°	°	°	°	°
July	31	186·09	0·25	+0·88	6·57	6·63	352·4
Aug.	1	198·31	0·27	−0·39	6·06	6·07	3·7
	2	210·54	0·30	1·62	5·29	5·53	17·0
	3	222·78	0·32	2·74	4·27	5·07	32·6
	4	235·02	0·35	3·69	3·04	4·78	50·4
	5	247·26	+0·37	−4·41	+1·65	4·71	69·4
	6	259·51	0·39	4·87	+0·15	4·87	88·2
	7	271·76	0·41	5·04	−1·39	5·22	105·5
	8	284·01	0·44	4·91	2·89	5·69	121·0
	9	296·26	0·46	4·50	4·26	6·19	133·5
	10	308·50	0·48	3·85	5·40	6·62	144·6
	11	320·74	0·51	2·99	6·23	6·91	154·5
	12	332·97	+0·53	−2·00	−6·70	6·99	163·5
	13	345·20	0·55	−0·93	6·75	6·82	172·2
	14	357·42	0·58	+0·17	6·40	6·40	181·5
	15	9·63	0·61	1·23	5·65	5·78	192·2
	16	21·84	0·63	2·21	4·56	5·06	205·8
	17	34·04	0·66	3·08	3·21	4·45	223·9
	18	46·23	0·69	3·82	1·67	4·17	246·4
	19	58·42	+0·72	+4·39	−0·05	4·39	269·3
	20	70·60	0·75	4·78	+1·54	5·02	287·9
	21	82·79	0·77	4·95	3·03	5·80	301·5
	22	94·97	0·80	4·89	4·32	6·52	311·5
	23	107·15	0·82	4·59	5·36	7·06	319·5
	24	119·33	0·85	4·05	6·12	7·33	326·7
	25	131·52	0·87	3·27	6·58	7·34	333·7
	26	143·71	+0·90	+2·28	+6·73	7·10	341·4
	27	155·91	0·92	+1·13	6·58	6·67	350·3
	28	168·11	0·94	−0·13	6·15	6·15	1·2
	29	180·32	0·96	1·42	5·45	5·63	14·6
	30	192·53	0·98	2·68	4·52	5·25	30·6
	31	204·75	1·00	3·81	3·37	5·09	48·4
Sept.	1	216·97	1·02	4·74	2·06	5·16	66·5
	2	229·10	+1·03	−5·38	+0·61	5·42	83·5
	3	241·43	1·05	5·69	−0·90	5·76	99·0
	4	253·66	1·07	5·62	2·40	6·11	113·2
	5	265·90	1·08	5·15	3·81	6·40	126·6
	6	278·14	1·10	4·32	5·03	6·62	139·4
	7	290·37	1·12	3·18	5·95	6·75	152·0

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Geocentric Libration. Amount.	Geocentric Libration. Direction
1888.		°	°	°	°	°	°
Sept.	8	302·60	1·13	1·85	6·51	6·77	164·2
	9	314·83	+1·15	−0·43	−6·65	6·66	176·3
	10	327·06	1·17	+0·96	6·37	6·44	188·5
	11	339·28	1·19	2·22	5·68	6·10	201·3
	12	351·49	1·21	3·29	4·65	5·69	215·2
	13	3·69	1·23	4·12	3·38	5·33	230·6
	14	15·88	1·24	4·73	1·88	5·09	248·3
	15	28·07	1·26	5·11	−0·32	5·12	266·4
	16	40·25	+1·28	+5·29	+1·23	5·43	283·1
	17	52·43	1·30	5·28	2·69	5·92	297·1
	18	64·60	1·32	5·09	3·99	6·49	308·2
	19	76·77	1·33	4·73	5·06	6·92	317·1
	20	88·94	1·35	4·19	5·86	7·20	324·6
	21	101·10	1·37	3·47	6·38	7·25	331·6
	22	113·27	1·38	2·57	6·58	7·07	338·8
	23	125·44	+1·39	+1·50	+6·49	6·67	347·0
	24	137·61	1·40	+0·30	6·12	6·13	357·2
	25	149·79	1·41	−1·00	5·48	5·57	10·3
	26	161·98	1·42	2·34	4·61	5·17	26·9
	27	174·17	1·43	3·64	3·53	5·07	45·8
	28	186·36	1·44	4·83	2·29	5·34	64·6
	29	198·56	1·45	5·81	+0·92	5·88	81·0
	30	210·76	+1·45	−6·48	−0·52	6·50	94·6
Oct.	1	222·97	1·46	6·77	1·99	7·05	106·4
	2	235·18	1·46	6·60	3·39	7·42	117·2
	3	247·40	1·47	5·96	4·64	7·54	128·0
	4	259·62	1·47	4·85	5·64	7·43	139·4
	5	271·84	1·48	3·36	6·30	7·14	152·1
	6	284·06	1·48	−1·60	6·55	6·74	166·3
	7	296·28	+1·49	+0·25	−6·35	6·36	182·3
	8	308·50	1·50	2·03	5·72	6·07	199·5
	9	320·71	1·50	3·60	4·72	5·93	217·2
	10	332·91	1·51	4·85	3·43	5·93	234·6
	11	345·11	1·52	5 75	1·96	6·07	251·2
	12	357·30	1·52	6·29	−0·40	6·31	266·3
	13	9·48	1·53	6·51	+1·14	6·61	279·9
	14	21·65	+1·54	+6·45	+2·58	6·95	291·9
	15	33·82	1·54	6·16	3·87	7·27	302·2
	16	45·98	1·54	5·68	4·94	7·52	311·1

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Long. of the Earth.	Lat.	Amount.	Direction.
1888.	°	°	°	°	°	°
Oct. 17	58·14	1·55	5·03	5·75	7·63	318·9
18	70·30	1·55	4·24	6·28	7·57	326·1
19	82·45	1·55	3·31	6·51	7·30	333·2
20	94·60	1·55	2·26	6·45	6·83	340·8
21	106·75	+1·55	+1·09	+6·10	6·20	349·9
22	118·90	1·54	−0·18	5·49	5·49	1·9
23	131·06	1·54	1·52	4·64	4·89	18·1
24	143·22	1·53	2·89	3·60	4·61	38·8
25	155·38	1·53	4·23	2·39	4·85	60·5
26	167·55	1·52	5·46	+1·06	5·56	79·0
27	179·72	1·51	6·49	−0·34	6·50	93·0
28	191·90	+1·51	−7·23	−1·76	7·44	103·7
29	204·08	1·50	7·60	3·13	8·18	112·0
30	216·27	1·49	7·50	4·38	8·67	120·4
31	228·46	1·48	6·88	5·42	8·75	128·4
Nov. 1	240·66	1·48	5·75	6·17	8·42	137·2
2	252·87	1·47	4·15	6·54	7·74	147·7
3	265·07	1·46	2·21	6·46	6·83	161·2
4	277·28	+1·45	−0·09	−5·93	5·93	179·1
5	289·49	1·45	+2·00	4·98	5·37	201·8
6	301·69	1·44	3·88	3·69	5·35	226·3
7	313·89	1·43	5·41	2·18	5·83	248·0
8	326·08	1·43	6·53	−0·56	6·55	265·1
9	338·26	1·42	7·21	+1·04	7·28	278·2
10	350·44	1·41	7·48	2·54	7·89	288·8
11	2·61	+1·40	+7·38	+3·86	8·32	297·7
12	14·77	1·39	6·98	4·95	8·55	305·5
13	26·93	1·38	6·34	5·78	8·57	312·5
14	39·08	1·37	5·50	6·33	8·38	319·2
15	51·22	1·35	4·52	6·58	7·98	325·7
16	63·36	1·34	3·41	6·54	7·37	332·6
17	75·50	1·32	2·22	6·20	6·59	340·4
18	87·64	+1·31	+0·95	+5·60	5·69	350·4
19	99·78	1·29	−0·38	4·76	4·78	4·5
20	111·91	1·27	1·72	3·71	4·09	24·8
21	124·05	1·25	3·06	2·50	3·95	50·7
22	136·19	1·23	4·35	+1·18	4·51	74·8
23	148·34	1·21	5·53	−0·23	5·54	92·4
24	160·49	1·19	6·54	1·64	6·74	104·1

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Long. of the Earth.	Lat.	Amount.	Direction.
1888.	°	°	°	°	°	°
Nov. 25	172·65	+1·17	−7·29	−3·00	7·85	112·5
26	184·81	1·15	7·71	4·25	8·80	119·0
27	196·98	1·13	7·72	5·32	9·36	124·7
28	209·15	1·11	7·25	6·13	9·48	130·4
29	221·33	1·09	6·30	6·60	9·11	136·5
30	233·51	1·07	4·87	6·66	8·25	144·0
Dec. 1	245 70	1·05	3·06	6·33	7·03	154·3
2	257·90	+1·03	−1·01	−5·46	5·55	169·6
3	270·10	1·01	+1·12	4·24	4·39	194·8
4	282·29	0·99	3·12	2·73	4·15	228·8
5	294·48	0·98	4·86	−1·05	4·97	257·8
6	306·67	0·96	6·21	+0·66	6·24	276·1
7	318·85	0·94	7·11	2·28	7·47	287·8
8	331·03	0·92	7·57	3·72	8·43	296·3
9	343·20	+0·90	+7·60	+4·91	9·04	303·0
10	355·36	0·88	7·26	5·81	9·29	308·9
11	7·52	0·85	6·61	6·42	9·20	314·4
12	19·67	0·83	5·71	6·71	8·81	319·7
13	31·81	0·81	4·63	6·71	8·15	325·5
14	43·95	0·78	3·42	6·41	7·25	332·0
15	56·09	0·75	2·13	5·83	6·21	340·0
16	68·22	+0·72	+0·80	+5·01	5·07	350·9
17	80·35	0·70	−0·53	3·97	4·00	7 6
18	92·48	0·67	1·83	2·75	3·30	33·6
19	104·61	0·64	3·07	+1·40	3·37	65·5
20	116·74	0·61	4·21	−0·02	4·21	90·3
21	128·87	0·58	5·23	1·46	5·42	105·7
22	141·01	0·55	6·06	2·85	6·69	115·3
23	153·15	+0·52	−6·66	−4·14	7·84	121·9
24	165·29	0·49	6·99	5·24	8·73	127·0
25	177·44	0·46	6·99	6·09	9·26	131·2
26	189·60	0·43	6·63	6·63	9·36	135·2
27	201·77	0·40	5·88	6·81	8·99	139·4
28	213·94	0·38	4·75	6·58	8·11	144·3
29	226·12	0·35	3·29	5·92	6·77	151·0
30	238·30	+0·33	−1·59	−4·86	5·11	161·9
31	250·49	0·30	+0·22	3·45	3·46	183·7
1889.						
Jan. 1	262·68	+0·28	+2·06	−1·80	2·73	228·7

These ephemerides supply the selenocentric places of the Sun and of the Earth, referred to the system of selenographical co-ordinates. The assumed inclination of the plane of the lunar equator to the ecliptic is = 1°·536. The computations have been made so that the last figures given can be relied on.

The geocentric libration or the selenographical position of the point on the Moon's surface which has the Earth's centre in the zenith is expressed not only by its selenographical longitude and latitude, but only by polar coordinates, of which the zero-point of longitude and latitude or the point corresponding to the centre of the lunar map is the pole. The "direction" of libration is referred to the central meridian of the map in the same way as angles of position are referred to the circle of declination, the zero-direction being that to the north pole of the Moon. The "amount" of libration is the combined effect of the librations in longitude and latitude, or the angular distance of the centre from the point which has the Earth in the zenith. A graphical representation of the libration curves for the nine lunations over which the ephemeris extends may be found in the library of the Royal Astronomical Society. The greatest librations during this period are those of

	h		°		°
Dec. 10	6	amount	9·30	direction	310·2
and of Dec. 25	17		9·38		134·0.

The selenographical colongitude (=90°—longitude) and latitude of the point on the Moon's surface which has the Sun's centre in the zenith, or, for briefness, the colongitude and latitude of the Sun serve in the computations of observations of all those phenomena on the Moon's surface which depend on the Sun's light, and they are available for the prediction of the recurrence of such phenomena as have been properly observed and timed. In a paper published in vol. xxxiii. of the *Monthly Notices*, pp. 139–156, a list, comprising 600 lunar spots, may be found, which supplies the data for determining by means of a trifling computation the Sun's colongitude, and consequently, if an ephemeris like the present one is available, the time when the Sun's centre is in the true horizon of any of these spots. When I get the next opportunity, I intend to examine all the lunar sketches in the library of the Royal Astronomical Society, and to prepare a proper list of those which deserve not to be left out and are at least approximately timed, the list being arranged in the order in which the Sun reaches the same altitudes above the horizon of the spots as at the times assigned to the sketches. I content myself at present with giving, as a specimen, a list of the sketches of M. Trouvelot, published in vol. viii. of the *Annals of Harvard College Observatory*, on Plates 4, 15, 18, and 20.

Sun's Colongitude.		Spot.	Time assigned. Camb. Mass. M.T.			Sun's Lat.	
				h	m		
321°·59 + 0·162	⊙'s Lat.	Guttemberg	1872, July	9	9	0 + 0·92	Trouvelot pl. 15
333·61 + 0·075	„	Torricelli	72, Mar.	14	9	30 − 1·52	4
340·02 + 0·086	„	Hypatia	72, June	11	10	0 + 0·23	15
341·72 − 0·274	„	Plinius	73, Jan.	4	6	0 − 1·05	18
345·29 − 0·155	„	Julius Cæsar	72, Mar.	15	9	0 − 1·52	15
351·59 − 0·528	„	Linné	73, Mar.	5	7	0 − 1·47	20
357·11 − 0·072	„	Agrippa	72, Mar.	16	8	0 − 1·52	4
357·15 − 0·047	„	Godin	„	„		„	„
5·47 − 0·870	„	Cassini	72, Oct.	9	8	0 + 1·16	18
6·84 + 0·231	„	Alphons	73, Jan.	6	6	30 − 1·09	18
6·89 + 0·285	„	Alpetragius	„	„		„	„
6·94 + 0·328	„	Arzachel	„	„		„	„
15·34 − 0·258	„	Eratosthenes	72, April	16	9	0 − 1·15	4
15·44 − 1·214	„	Plato	73, Mar.	7	8	0 − 1·46	20
15·72 − 1·023	„	Pico	„	„		„	„
18·82 + 0·073	„	Fra Mauro	73, Jan.	7	6	30 − 1·12	18
18·91 + 0·165	„	Parry	„	„		„	„
18·93 + 0·182	„	Guerike	„	„		„	„
35·72 + 0·329	„	Agatharchides	72, Sept.	12	10	0 + 1·50	15
49·04 + 0·309	„	Gassendi	73, Feb.	8	8	0 − 1·53	20
58·87 − 0·433	Lat.	Aristarrh	1873, Jan.	10	5	0 − 1·18	Trouvelot pl. 20

In order to ascertain the time when for a spot of the list the Sun is at the same zenith distance as at the time assigned to the sketch, it is only required to multiply the Sun's latitude (taken from the ephemeris for the approximate time of the occurrence) by the factor given in the second column of the list, to add the product to the number in the first column, and to determine by reference to the ephemeris the time when the Sun reaches the colongitude thus found. Though the Sun's zenith distance will then be the same as at the time of the sketch, the effects of the illumination may yet differ sensibly, as they depend also on the Sun's azimuth, and they will therefore only agree if the Sun's latitude is the same on both occasions. Hence the necessity for the column in the list which gives the Sun's latitude at the time of the sketch.

As the daily rate of increase of the Sun's colongitude is 12°·12 to 12°·25, the ephemeris is sufficiently accurate for finding the time to about a minute. But the time thus found is merely that corresponding to the assigned time of the sketch, and any error of the assigned time is simply reproduced. M. Trouvelot's elaborate sketches must have been the work perhaps of hours, and the assigned times may differ considerably from the times

when the shadows in different parts of the sketches have actually been drawn. This may not matter much if the sketches are intended merely to be fair representations. But if the evidence of sketches is to be used in determining the heights of mountains, &c., it is clearly essential that the correct times should be stated when the shadows have actually been drawn. As a striking illustration I may perhaps refer to the latest lunar sketch which has come under my notice, Mr. Elger's interesting sketch of Plato and the region to the south of it, published on Plate x. of vol. vi. of the *Journal* of the Liverpool Astronomical Society.

The sketch represents the shadow of the spire-like pic Plato γ at a time when the point of the shadow has already quitted the crest and is on the inner slope of the opposite wall. Such an occasion affords a very favourable opportunity for procuring most valuable evidence for the determination of the differences of level between the top of the pic γ and the crest of the opposite wall and the floor of Plato. This evidence is secured by watching for and recording the times when the point of the shadow is on the crest of the wall or just quits the crest, and when it gets to the bottom of the slope and enters upon the floor, and by indicating the exact locality. Mr. Elger's sketch clearly indicates the locality, but what information is given about the time? The sketch itself is not even dated, and the time, 6h. on February 1st, 1887, which is found in the text as that when the drawing was made, is probably merely the approximate middle of the whole time expended upon the drawing. However, the time stated will at least allow the prediction of the occurrence of similar opportunities.

The Sun's selenocentric position was 1887, February 1, $6^h\ 0^m$, G.M.T., in colong. 11°·37 and lat. +0°·46. At the assumed place of Plato γ the zenith distance of that time will be reached by the Sun when the colong. is $= 11°{\cdot}92 - 1{\cdot}205 \times$ Sun's lat., and therefore, according to the data of the ephemeris, at the following times:—

1888.	G.M.T. h m	⊙'s Lat. °	1888.	G.M.T. h m	⊙'s Lat. °	1888.	G.M.T. h m	⊙'s Lat. °
April 19	11 19	−1·53	July 16	17 49	−0·17	Oct. 13	1 11	+1·53
May 18	22 47	−1·40	Aug. 15	3 3	+0·61	Nov. 11	15 27	+1·39
June 17	8 41	−0·90	Sept. 13	13 15	+1·24	Dec. 11	8 26	+0·84

But as the Sun's latitudes on all these occasions are different, the localities where the point of the shadow falls will also differ and the times will also be affected, so that there will be interesting variety; and the extension of the observations to other pics Plato δ, ϵ, ζ, Pico, &c., and, in due course, to all other interesting lunar spots, will provide observers with ample opportunities for exercising their patience and skill and for making really *useful* observations.

[*Comet Sawerthal*, 1888. By David Gill, LL.D., F.R.S.

(*Extract from a letter to Mr. Knobel.*)

You have already heard by telegram of the comet discovered by Sawerthal. Early in the morning of February 19 he was returning from the Photographic Observatory (where he is engaged by me on the work of the *Durchmusterung*) when he saw what looked suspiciously like a comet, and he at once verified his suspicion by the aid of an opera-glass. He at once called Mr. Finlay, who had been busy comet-seeking in the early morning for the past fortnight, and a place was determined. Next morning I observed it with the heliometer, and we are now getting a strong series of observations. Approximate elements have been telegraphed home, and you will have the comet to answer for itself in the northern hemisphere about or rather before the time that this reaches you. Perihelion is on March 18.

The reflected light of the comet will now exceed $1\frac{1}{2}$ times that at the time of discovery, and, as perihelion distance is about $\frac{2}{3}$, it seems doubtful if it will become greatly brighter from increased development of tail. It will remain an early morning object during its time of visibility.

Royal Observatory, Cape of Good Hope:
1888, *March* 4.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. APRIL 13, 1888. No. 6

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

John Edmund Drower, May Trees, Endlesham Road, Balham, S.W.;
George James Newbegin, Esq., Thorpe St. Andrew, Norwich; and
Captain George William Read, F.R.G.S., 1 Broad Street, Penrhyn, Cornwall,

were balloted for and duly elected Fellows of the Society.

On the Occultations of Döllen's list of Stars, observed at the Royal Observatory, Cape of Good Hope, during the Total Eclipse of the Moon, 1888, January 28. By David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape.

In accordance with Dr. Döllen's request, preparations were made for observing, during the total eclipse of the Moon on January 28, the occultations of stars whose times of disappearance and reappearance had been computed by him for this observatory.

It is to be regretted that his letter containing the request in question only reached the Cape about a week before the eclipse, otherwise it might have been possible to comply with his further request—viz. to establish another temporary observatory twenty or thirty miles distant, so that the same occultations might be observed at slightly different parts of the limb, and thus the effect of accidental irregularities of the limb on the resulting parallax and diameter might be, to some extent, eliminated.

Under existing circumstances, however, all that could be done was to forward without delay to Mr. Nevill, Director of the Natal Observatory (better known to astronomers as Mr. Neison), a copy of the list of stars with an explanation of Dr. Döllen's request, and Mr. Nevill was fortunately able to make such good use of his time as to compute the necessary predictions,

and to secure observations of ten disappearances and seven reappearances, the particulars of which he will doubtless communicate to the Society.

The observers and instruments at the Cape, together with the coordinates of their points of observation relative to the transit-circle, are given in the following Table I.

The error of the normal transit clock was determined by observations of four time stars by Mr. Finlay and two pole and two time stars by Mr. Maclear. The means of their determinations have been adopted. The observations for time were made by the eye and ear method, the beats of the clock being rendered audible by a "sounder" in the chronograph circuit.

The times of disappearance and reappearance were recorded at the heliometer and the 7-inch and 6-inch equatorials on local chronographs placed in these observatories in circuit with the transit clock. The observations with the 5-inch guiding telescope of the stellar photographic apparatus were made by "eye and ear," with a chronometer which was compared with the normal transit clock (using the beats of the sounder) before and after the observations.

The times of the phenomena as recorded by the various observers are given in the following list, together with the notes of the observers.

The eclipse of 1888 was remarkable for the brilliancy of the eclipsed disc of the Moon as compared with that of 1884. This brilliancy rendered it impossible, at least with the comparatively small instruments at disposal, to observe the disappearance or reappearance of the faintest stars on the list. With the 5-inch telescope it is certain that in several instances the light of the neighbouring limb of the Moon produced apparent occultation too soon and apparent reappearance too late, and no certain distinction between true and apparent phenomena appears to have been drawn by the observer. These doubtful cases are marked (?), and should not be employed in the discussion of results.

Had it fortunately happened that similar conditions as to the brilliancy of the eclipsed Moon had occurred in 1888 as in 1884, it is probable that the whole of the predicted occultations might have been observed. The sky was beautifully clear throughout totality.

TABLE I.

Observer.	Instrument.	Aperture in inches.	Position relative to transit-circle in feet.	
		Inches.	Feet.	Feet.
Gill	Heliometer (one segment of the object-glass only used)	7¼	N. 200	E. 58
Finlay	Merz Equatorial	7	N. 197	W. 145
Maclear	Guiding telescope of the star photographic apparatus	5	S. 365	E. 52
Cox	Grubb Equatorial	6	S. 393	E. 75

TABLE II.

Local Sidereal Times.

Star's Number on Döllen's List.	Phenomenon Observed.	Observed by D. Gill.	Observed by W. H. Finlay.	Observed by G. Maclear.	Observed by W. H. Cox.
		h m s	h m s	h m s	h m s
127	D.	...	8 14 36·8	8 14 35·6	
121	D.	...	(*c*) 16 1·2	15 55·6?	
76	R.	...	24 40·9	...	
146	D.	8 28 28·2	28 26·4	28 26·7	
143	D.	29 5·3	(*d*) 29 4·8	...	
147	D.	...	...	31 41·2?	
122?	R.	(*a*) 31 40·8	...	...	
88	R.	...	31 44·4	...	
95	R.	(*b*) 44 20·0	...	44 53·4?	
158	D.	...	56 30·3	...	
159	D.	58 45·3	(*e*) 58 45·4	58 45 6	
111	R.	...	9 0 50·9	...	
107?	R.	...	...	9 0 59·0?	
	R.	...	...	1 25·1?	
121	R.	...	9 2 54·9	3 9·4?	
113	R.	...	5 57·8	6 29·4?	
127	R.	9 21 10·7	...	21 14·3?	
173	D.	...	23 29·8	...	
132	R.	...	...	(*k*) 27 46·4?	
191	D.	28 6·8	...	...	(*m*) 9 28 6·7
189	D.	43 17·0	(*f*) 43 15·9	43 9·9?	
179	D.	50 39·1	(*g*) 50 39·1	(*l*) 50 38·9	
146	R.	...	(*h*) 53 59·9	...	

Notes.

(*a*) Position-angle 189°.

(*b*) Doubtful. [Note.—This star was noted by Mr. Finlay as "some way from the limb" at $8^h\ 44^m\ 29^s$, and even at $44^m\ 20^s$ it was not *certain* that the first instant of reappearance had been observed.—D. G.]

(*c*), (*d*) Uncertain. (*e*), (*g*), (*h*) Good.

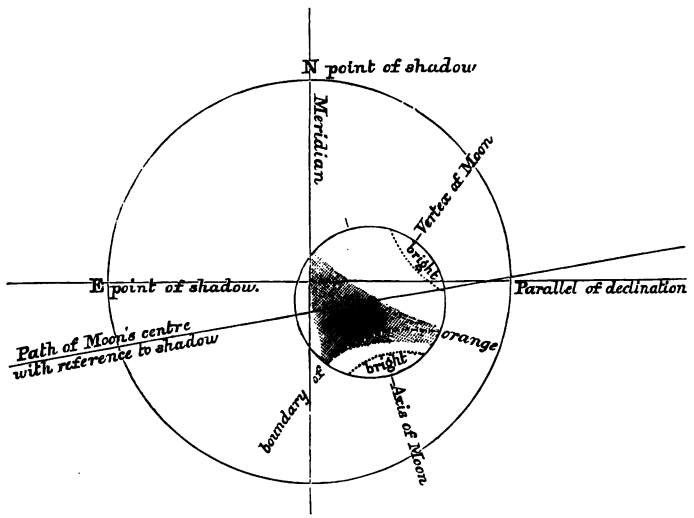
(*f*) Very good. Star seen within Moon's limb.

(*k*) Perhaps a little late. Very faint. (*l*) Very good. (*m*) Very good.

The Total Eclipse of the Moon, 1888, January 28.
By T. W. Backhouse.

(*Abstract.*)

The general appearance was very much the same as in the total eclipse of 1866, March 30—perhaps a more brilliant orange, the greater part of the shadow being of that colour, while the border was yellow, and the extreme edge white, if not bluish. The total light of the Moon was least about the middle of the eclipse, at which time, as seen out of focus through an opera-glass reversed, and by indirect vision, it appeared to be two-thirds as bright as *Saturn*, and about two and a half times as bright as *Pollux*. At 10·50 it was twice as bright as *Saturn*.



At 10·52 the lower half of the Moon, with the exception of those portions towards the right-hand and the left-hand parts of the lower limb, seemed abnormally dark, the darkest part being a little south of the centre. I send a drawing of this abnormal darkness, as well as I could ascertain it apart from the lunar features, showing its position in the Earth's shadow. It was difficult to separate the abnormal darkness from the lunar features, and it is quite likely that the extreme darkness of the portion near the middle was partly due to Mare Nubium, though unfortunately I did not record its exact position relative thereto. The brightness of the lower left-hand limb was probably due to the lunar features and not to any difference in the intensity of

the Earth's shadow at that part. The actually brightest portions of the Moon were those two marked with the dotted lines, viz. the lower right-hand portion, and the upper portion between Mare Tranquillitatis and the limb. As the region between these two parts was that nearest the edge of the Earth's shadow, I conclude that the abnormal darkness really extended right across the Moon, mainly in a broad irregular belt from position-angle 250° to 130°.

There was also a difference in colour between the northern and southern parts of the right limb not to be accounted for by the distance from the edge of the shadow, there being no tinge of orange but only yellow in the south preceding part marked off by the broken line, while all the rest of the disc was orange.

I noted the occultation of a bright star at $10^h\ 38^m\ 51^s$ (with a possible error of about 1 second or perhaps 2 seconds); it disappeared instantaneously at position-angle about 110°.

Sunderland: 1888, *February* 27.

The Total Eclipse of the Moon, 1888, *January* 28.

By W. F. Denning.

(*Abstract.*)

This phenomenon was observed at Bristol under the best possible conditions of weather. The sky was cloudless the whole time.

As soon as the umbra had well entered upon the Moon's limb I observed that it was not nearly so dark as in the eclipse of 1884, October 4. On that occasion during the partial phase I could not discern the outline of the Moon at all in my 10-inch reflector until near the period of totality, when it became feebly perceptible. But in the present instance the immersed limb was very obvious, and it could be distinguished with the naked eye, especially after 10^h, the appearance being very similar to what is observed near the time of new moon, when our satellite is faintly visible in full outline by the effects of earthshine.

The total phase was reached at $10^h\ 31^m$, and now the Moon's disc displayed a vivid extent of colouring. The entire surface remained distinctly perceptible to the naked eye, the brightest coppery hues being upon the upper limb where the outer limits of the shadow fell. The interior parts were suffused in a red glow of varying depth. At the middle of totality the darkest tints were near the Moon's centre, while the marginal zone was quite bright by contrast, and enabled the globe of our satellite to be sharply defined upon the background of dark sky. On October 4, 1884, the central part was much the brightest at the middle of the eclipse, while the extreme faintness of the outer

region had the effect of greatly reducing the Moon's diameter, so that to the naked eye it looked like a planet struggling through dense haze or a nebula with ill-defined outline.* The appearance of the Moon on the two occasions was therefore utterly dissimilar, and proves that some remarkable change had occurred in the condition of our atmosphere as the medium of refracting a portion of the solar rays to the Moon when in eclipse.

When we consider that the great ring of air concerned in this refraction includes every climate existing between the poles, and that it varies rapidly in longitude owing to the Earth's rotation, it will be seen that any local or partial effects must be annihilated, and that, if our atmosphere is really the chief agent in producing dark and light eclipses, its *general* humidity must undergo surprising changes.

Bristol: February 1888.

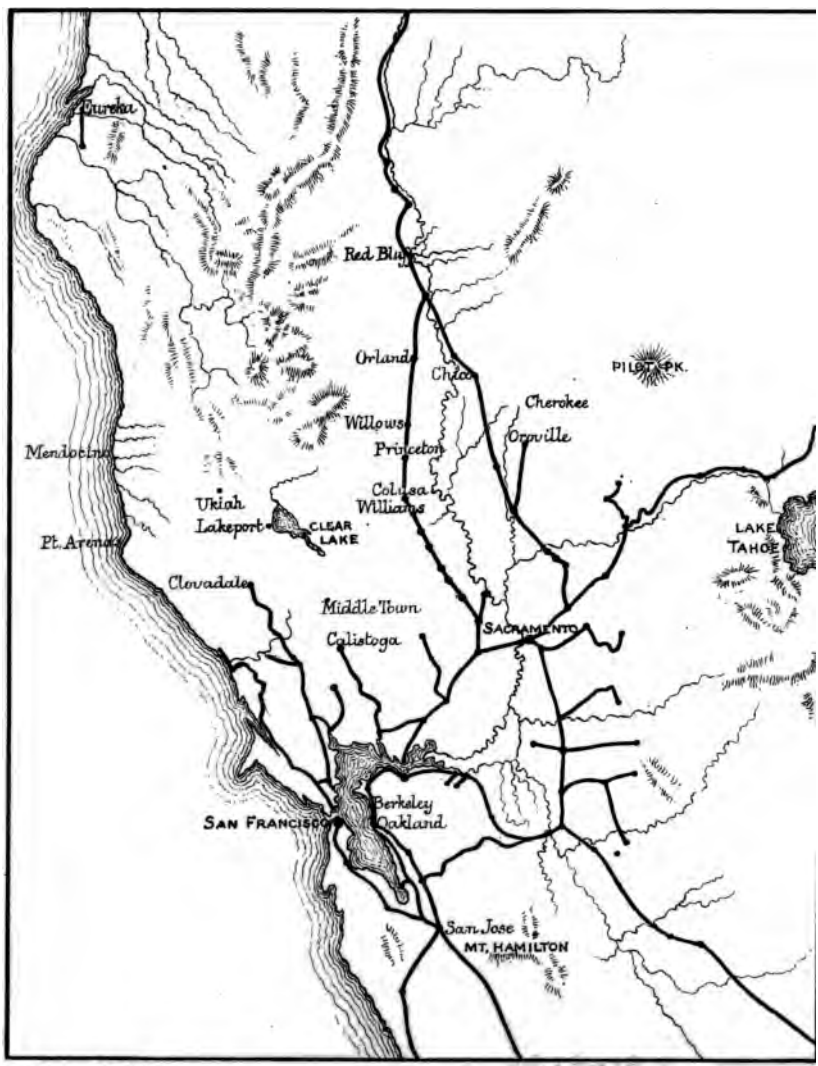
The Total Solar Eclipse of 1889, *January* 1, *in California. Probable Meteorological Conditions at that Time.* By Edward S. Holden, LL.D., Foreign Associate, R.A.S.

(*Extract from a letter to Mr. Knobel.*)

In order to assist intending observers of this eclipse to form their programmes of observation, I have requested the authorities of the U.S. Signal Service at Washington and at San Francisco to furnish extracts from their records of cloudiness at various Californian stations near the line of total eclipse for the last fifteen days of December and the first fifteen days of January. This request has been courteously complied with, and the data available are printed in the tables which follow, as well as some others which I owe to the kindness of Major Heuer, U.S. Corps of Engineers, Inspector of Lighthouses in California. In order to draw conclusions from these tables, it is necessary to say a few words on the climate of California as affected by topographic conditions.

During the greater part of the year the ocean near the coast is covered by fogs. The coast towns, as Mendocino, Eureka, Punta Arenas, &c., thus have a high percentage of cloudiness. The coast range of mountains on its western (seaward) slope is a region of comparatively great rainfall, therefore the eastern slope of these mountains is likewise considerably affected. The interior valleys, as the valley of Clear Lake (Lake County) and the great Sacramento Valley, being protected from the prevailing western winds, are far more sunny, and this is true during the whole year. January is a particularly unfortunate time of year for astronomical work, since it falls in the middle of the wet season, when it is possible that rainy periods of a week or more may be experienced all over northern California.

* *Monthly Notices*, vol. xlv. p. 43.



Spottiswoode & Co. Lith. London.

Railway Map of Northern California.

At the close of the rainy season (about April), unbroken clear weather may be expected for a period of six months or more, as may be seen by referring to the meteorological records in vol. i. of the *Publications of the Lick Observatory.*

Transportation.

Railways lead from San Francisco to Cloverdale (Sonoma County), to Calistoga (Napa County), to Colusa, &c. (Colusa County), to Oroville, &c. (Butte County), as may be seen from the accompanying railway map. From the various railway stations good waggon roads lead to all points likely to be chosen for observing stations, and there will be no difficulty in procuring suitable transportation by stages or waggons, nor in finding mechanics and labourers. Punta Arenas can also be readily reached, and tolerably comfortable quarters can be secured there and at other stations.

Intending observers from England or the Continent may best bring their instruments as personal luggage by steamer to New York. At New York the boxes will have to be opened at the Custom House, and the boxes should be so fastened as to readily allow the examination. The instruments will be admitted free of duty if a special permit be obtained from the Secretary of the Treasury at Washington. No doubt Professor Newcomb, the Director of the American Ephemeris at Washington, or any of the astronomers at the Naval Observatory at Washington, would be glad to expedite free entry of such instruments, if they were communicated with by letter a month or so before leaving England. I am, of course, not authorised to speak for them, except in this general way, but I have no doubt that suitable arrangements will be promoted by them, and announced to intending observers in due time. I understand that Congress will be asked to appropriate a sum of money for the observation of this eclipse.

The instruments should be shipped *by express* from New York to San Francisco, and they will be found at Wells, Fargo & Co.'s express office in the latter city.

From San Francisco the boxes can be *expressed* to almost any point in California by the same company.

Observing Parties.

The Lick Observatory will send at least one observing party to the central line. The eclipse will also be observed by parties under the direction of Professor Davidson, of the U.S. Coast and Geodetic Survey. The permanent observatory of Professor Davidson (San Francisco), the Students' Observatory of the University of California (at Berkeley), the Chabot Observatory (at Oakland), the Lick Observatory (near San José), and various private observatories in California, will also take part in the work. No doubt a considerable number of eclipse expeditions will be formed in the Eastern States and sent to California.

Time Signals.

Time signals sent from the Lick Observatory are received daily (at Pacific standard noon) at nearly every railway station in California. On the days immediately preceding and following the eclipse, they will be automatically transmitted from our standard clock, and special pains will be taken to make them useful to observing parties in the field.

The Positions of the Observing Stations

will, in general, have to be determined by observation, as no accurate topographical survey has been made for the interior of California. Points near the coast will have been accurately determined by the U.S. Coast and Geodetic Survey parties. Stations in the interior can usually be connected with the permanent marks of the (rectangular) surveys of the U.S. Land Office.

The Lick Observatory.

I hope that none of our foreign visitors will leave California without paying a visit to the Lick Observatory, where our corps of astronomers will be pleased to receive them. As our accommodations for guests to the mountain are quite limited, it is necessary that an appointment for the visit should be made several days in advance, and I would ask correspondence in regard to this. I regret that the opportunity for such visits falls in our most unfavourable season, but I shall hope for weather clear enough to enable some idea to be formed of our instruments and equipment. At any rate, I am sure that I can promise to all our foreign guests a magnificent mountain view, and a hearty welcome.

Meteorological Data.

The tables follow in the form in which I have received them. With a map of the region and with the explanations I have given, each intending observer can use his own judgment in the selection of a station. I have preferred not to express any definite opinion on a subject so uncertain as California weather in January, but to present the data simply.

General Average Cloudiness for Each Day at Four California Stations, from the Records of the U.S. Signal Service.

Stations.	Year.	DECEMBER. 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	JANUARY. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Eureka, Cal.	1886–7																	00	57	47	60	100	100	47	00	70	60	93	100	67	67	57
	1887–8																	100	100	47	67	57	37	27	00	00	17	77	67	67	00	30
Cape Mendocino, Cal.	1885																	Average *daily* cloudiness, January 1885, 61·7														
	1885–6	33	83	13	17	83	80	100	100	100	100	47	40	13	37	27	53	00	37	00	17	40	43	10	50	00	17	87	100	90	87	50
	1886–7	50	67	27	40	40	100	100	33	17	87	50	87	100	67	87	40															
Red Bluff, Cal. ...	1885																	Average *daily* cloudiness, January 1885, 46·7														
	1885–6	100	67	00	100	100	100	67	100	100	67	37	00	00	100	47	30	00	20	00	27	00	10	00	13	00	70	70	60	67	70	70
	1886–7	87	60	47	50	40	97	97	83	60	67	100	83	100	100	100	00	27	60	00	57	30	20	00	10	00	43	87	90	100	67	57
	1887–8	7	7	00	00	00	27	7	17	30	43	47	83	100	97	80	73	100	100	7	67	40	00	23	10	00	00	00	00	30	3	33
Sacramento, Cal. ...	1885																	Average *daily* cloudiness, January 1885, 52·3														
	1885–6	63	100	100	100	100	87	67	93	87	67	63	00	13	00	100	23	00	00	00	00	00	00	00	00	00	00	60	33	00	00	53
	1886–7	80	13	00	17	00	60	67	67	53	80	90	23	100	100	67	00	00	33	00	30	23	00	00	00	00	00	00	33	67	67	67
	1887–8	00	00	00	00	00	13	00	00	00	43	60	43	100	100	20	7	100	100	60	30	100	47	00	00	00	00	00	33	37	00	10

Percentage of Cloudiness at Noon at Four California Stations from Records of the U.S. Signal Service.

Stations.	Year.	DECEMBER. 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	JANUARY. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Eureka, Cal.	1887																	100	50	40	100	100	100	40	00	00	80	100	100	100	100	70
	1888																	100	100	40	100	70	50	60	00	00	50	100	100	100	00	90
Cape Mendocino, Cal.	1885																	Average cloudiness *at noon*, January 1885, 6·0														
	1885–6	100	70	00	50	80	100	100	100	100	100	30	30	40	40	00	60	00	80	00	00	70	30	30	80	00	00	100	100	100	80	70
	1886–7	50	100	50	40	70	100	100	100	100	90	100	60	100	100	90	50															
Red Bluff, Cal. ...	1885																	Average cloudiness *at noon*, January 1885, 5·1														
	1885–6	100	100	100	100	100	100	100	100	100	100	10	00	00	100	40	10	00	60	00	80	00	00	00	40	00	00	00	80	100	100	100
	1886–7	80	80	30	80	80	100	90	80	80	100	100	90	100	100	100	40	20	80	00	80	50	10	00	30	00	30	90	70	100	100	70
	1887–8	20	20	00	00	00	60	20	10	70	80	40	100	100	90	90	100	100	100	10	100	20	00	20	00	00	00	00	00	40	00	00
Sacramento, Cal. ...	1885																	Average cloudiness *at noon*, January 1885, 6·0														
	1885–6	90	100	100	100	100	100	100	100	90	70	90	00	40	100	100	70	00	00	00	00	100	00	00	00	100	100	100	100	100	00	80
	1886–7	100	00	00	50	00	80	50	10	60	70	100	30	100	100	100	00	00	100	00	90	00	00	00	00	00	00	00	00	100	100	100
	1887–8	00	00	00	00	00	40	00	00	00	30	50	90	100	100	30	100	100	100	00	90	100	40	00	00	00	00	00	00	80	00	30

Fog Signal Station, Punta Arenas, Cal.

Dec.	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Year.																	
1881	cloudy	clear	clear	clear	cloudy	cloudy	clear	clear	rain	clear	clear	rain	fog	fog	fog	clear	cloudy
1882	fog	fog	...	...	...	...	fog	fog	fog	fog	fog	...	...	...	...	...	...
1883	fog	fog	fog	fog	...	...	...	...	...	...	fog	fog	...	...	...	fog	fog
1884	...	...	fog	fog	fog	...	fog	fog	fog	...	...	...	...	...	...	...	...
1885	fog	fog	fog	fog	fog	...	...	...	...	...	...	...	...	...	...	...	...
1886	rain	rain	clear	clear	some fog	clear	clear	hazy	fog	hazy	clear	clear	rain	rain	rain	clear	fog
1887	rain	clear	clear	clear	clear	clear	clear	clear	clear	clear	hazy	rain	rain	rain	showers	showers	rain

'Fog' really means that there was use for the fog signal at times during the 24 hours, or for the whole day.

Fog Signal Station, Punta Arenas, Cal.

Jan.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year.															
1882	cloudy	rain	cloudy	fog	fog	clear	clear	clear	clear	clear	clear	clear	clear	clear	clear
1883	...	...	...	...	...	...	fog	fog	...	fog	...	...	...	...	...
1884	...	...	fog	fog	...	...	...	...	...	...	...	...	...	...	...
1885	...	...	fog	fog	fog	fog	fog	fog	...	...	...	...	...	...	...
1886	clear	clear	clear	clear	clear	clear	clear	clear	clear	cloudy	cloudy	rain	rain	clear	rain
1887	fog	clear	clear	clear	clear	clear	clear	clear	clear	clear	clear	fog	fog	rain	clear
1888	rain	rain	clear	snow	snow	snow	clear	clear	clear	clear	clear	clear	clear	clear	rain

'Clear' really means that there was no necessity for the fog signal. The sky may have been somewhat overcast.

The following statistics of the total mean monthly rainfall for a few stations near the line of totality may be of some slight moment in determining the relative value of the various places named. No really definite conclusions can be drawn from these, however, for two reasons, *first*, because the rainfall from year to year varies enormously, and *second*, because the rainfall at stations only a little distance from those named in the table may differ largely from the precipitation there set down on account of local topographical reasons.

[*From the Report of the State Engineer on Physical Data of California* (1886).]

Monthly Means of Rain and Melted Snow.

Stations.	Years.	Annual Rainfall. Inches.	Rainfall, December. Inches.	Rainfall, January. Inches.
Butte County:				
Cherokee	1871–84	43·9	6·08	8·37
Cherokee Reservoir ...	1873–79	60·3	5·77	13·35
Chico	1870–84	20·3	3·55	4·23
Oroville	1880–82	18·9	7·64	4·58
Colusa County:				
Colusa	1871–84	17·2	3·25	3·73
Orland	1882–84	14·7	0·47	1·95
Princeton	1873–84	14·9	2·18	3·24
Williams	1876–84	12·2	1·69	2·83
Willows	1878–84	11·5	2·31	2·09
Lake County:				
Kono Tyee, near Lakeport	1873–84	21·3	2·26	5·13
Middletown	1879–84	41·9	8·67	7·66
Mendocino County:				
Punta Arenas	1875–84	30·5	3·71	6·46
Ukiah	1876–84	32·5	4·69	7·07

Note on Mars. By Richard A. Proctor.

Mars should be carefully observed in June and July for duplication of the "canals" as Martian autumn is approached. Regarding these curious double dark streaks (or rather the bright streaks between them and the fainter streaks on either side of them), as the diffraction-images of Martian rivers at times when mist hangs over the river-beds, as I suggested four years since in the *Newcastle Weekly Chronicle*, we may expect the phenomena to be as noticeable when Martian autumn is approach-

ing as after Martian spring has begun (the reference is to the northern hemisphere, to which the double canals chiefly belong).

I suppose no one regards the double canals as objective realities; but, on the other hand, no one can regard them as optical *illusions*. Regarding them as phenomena of diffraction—that is, as optical *products*—we find an explanation at once of their variable appearance (since when the rivers look dark, as they usually must, on a light ground the duplication would not be observed), of their synchronising with the seasons, and of their being visible only with telescopes between certain limits of aperture. This last consideration suggests an effective method by which this diffraction theory can be put to the test.

It would be well if the appearances seen by Schiaparelli could be seen and delineated by observers possessing the power of delineating them with some degree of artistic skill. No one who has ever seen *Mars* through a good telescope can accept the hard and unnatural configurations depicted by Schiaparelli. The drawings of Dawes, Burton, Knobel, Denning, and Green are far more satisfactory, though some minute details seen by Schiaparelli may not have been within the telescopic range of these careful observers.

It is, I imagine, hopeless to expect that the most powerful of the telescopes constructed within the last quarter of a century will be applied to any work so thoroughly within their power as the examination of the planets' discs for features detected or suspected under the scrutiny of weaker telescopes. It seems to be thought so much more satisfactory to apply these splendid instruments to work which smaller telescopes cannot attempt, that micrometrical observations of the satellites of *Mars*, of *Hyperion*, or of exceedingly minute double stars, must be supposed to add amazingly to our knowledge of the universe, since the large telescopes are so diligently turned on such work, and so carefully kept from entering on work which has already been begun by smaller instruments. Unfortunately all the more important lines of research have been opened with telescopes of comparatively inferior power; so that if the dignity of the larger instruments requires that they shall be used only on lines of work which they and they only can open, we must fear that their work will rather be unique than specially interesting.

Corona Lodge, Orange Lake, Fla.:
1888, *March* 31.

Observations of Comet a, 1888 (*Sawerthal*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

Comet a, 1888 (*Sawerthal*).

Greenwich Mean Solar Time.	Observer.	♂−✱ R.A.	Corr. for Par. and Refraction in R.A.	♂−✱ N.P.D.	Corr. for Par. and Refraction in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1888 d h m s		m s	s	′ ″	″		h m s	° ′ ″	
April 6 16 15 6	H. T.	+0 55·95	−0·30	− 6 14·5	−6·4	6	22 18 27·45	81 0 7·5	*a*
6 16 19 41	,,	−0 38·73	−0·20	+14 35·4	−3·9	4	22 18 29·78	81 0 10·5	*b*

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1888·0.	N.P.D., 1888·0.	Authority.
		h m s	° ′ ″	
a	Lalande 43672	22 17 32·74	81 6 20·4	Second Armagh Catalogue.
b	W. B. XXII. 368	22 19 9·63	89 45 30·9	Glasgow Catalogue.

The observations are corrected for parallax and refraction.

The initials H. T. are those of Mr. Turner.

The comet has been looked for on a number of other mornings, but bad weather has prevented its being seen.

The New Southern Comet. Observations made at Graham's Town, Cape of Good Hope. By L. A. Eddie.

1888, *February* 25.—I obtained this morning a good view of the comet now visible in our south-eastern heavens, situated in the constellation *Telescopium*. It has a very condensed nucleus, equal in magnitude to a 4th magnitude star. The tail could be traced to τ *Telescopii*, 8° from the nucleus, and it possessed some considerable lustre to a point about 3° from the head, where it was fully 30′ in breadth. A decided curvature could be observed with the concavity towards the south. When viewed through the 9½-inch Calver it appeared a magnificent object of a deep golden colour, with highly condensed nucleus possessing a nucleolus, or tiny point of brilliant light in the centre. The nucleus was more sharply defined on its posterior border, but no dark interval was traceable. There was but little coma preceding the nucleus, but that around and behind was remarkably brilliant, and was very markedly curved on the southern border immediately surrounding the nucleus. The southern border of the tail was more sharply defined though more rugged in its outline. It was rendered invisible to the naked eye by the daylight at 5 o'clock; the Sun rose at 5·49.

When viewed in the reflector as the day advanced it assumed a variety of interesting forms.

At one time it appeared as a barbed spear, the barbed head resembling two wings; then these faded away and it resembled a ball of fire on the end of a luminous stick; lastly a fluffy ball of pale light alone remained, all vestige of tail and surrounding coma having faded away.

February 28.—The comet was scarcely visible to the naked eye owing to the brightness of the full Moon at $3^h\ 30^m$ A.M.

It did not appear to have increased in brilliancy. The only change I could detect was a widening of the coma in advance of the nucleus, and a slight trace of dark intervals therein dividing it into cometic envelopes, as in Coggia's Comet of 1874.

March 4.—After a number of cloudy mornings comet again visible in a clear sky. Notwithstanding the brightness of the moonlight it formed a conspicuous object with a tail 3° in length to the unaided vision. On comparing it with the neighbouring objects I concluded that it had slightly increased in brilliancy, and was equal to a star of 3½ mag. When viewed in the reflector the tail appeared ruddy, and the nucleus a greenish yellow. The latter was very brilliant, and surrounded by a coma which seemed to proceed in a double jet of faintly luminous matter from the centre of the nucleus to a short distance in front of it, and was then bent back to the right and left into the tail, the interval between these jets being filled with cometic matter of still fainter luminosity. The tail immediately

behind the nucleus was remarkably bright and condensed towards its axis.

March 5.—Comet bright but still much marred by moonlight; no perceptible change either to naked vision or in telescope.

Approximate Positions.

Graham's Town M.T.					
d h m	h m		° ′		
Feb. 24 15 15	R.A. 19 48	N.P.D.	138 35		
27 16 15	,, 20 11	,,	133 45		
March 3 16 0	,, 19 22	,,	125 50		

March 19.—The comet is still visible, and was last seen by myself on the 17th, when it appeared to be still equal to a 4th mag. star, and when viewed in the 9-inch Calver, a very bright object, with a tail of highly condensed matter which bore well a power of 100. The nucleus appeared to be slightly diffused on the preceding border. The tail was 6° in length before Venus-rise on March 13, when I obtained a favourable view of the comet; but after Venus-rise it could not be traced further than $2\frac{1}{2}°$ or 3° beyond the head. When viewed in the reflector the tail could be seen as sharply defined on both borders to about 2°, where it suddenly narrowed to about half its width, the northern half only being continued with sharp outline on its exterior, but rugged on the interior.

Approximate Positions.

d h m	h m s		° ′
March 8 16 0	R.A. 20 45	N.P.D.	118 30
9 16 0	,, 20 47 30	,,	117 30
12 16 20	,, 20 59	,,	112 30
14 16 0	,, 21 4 30	,,	109 40
16 16 30	,, 21 11 30	,,	106 30

Sextant Observations of Comet a, 1888.

By Captain James Clarke, R.N.R., s.s. *Olbers*.

(*Communicated by Captain H. Toynbee.*)

1888, February 26, 4 A.M., apparent time at ship in latitude 30° 1′ S., longitude 48° 30′ W. Greenwich date, February 25, $19^h\ 18^m\ 10^s$.

			° ′
Comet bearing from	Antares	S.E. by S.	46 11
,, ,,	α Centauri	East	46 48
,, ,,	Altair	S.W. by S.	55 15

Length of tail from nucleus, 4°.

Observations of Comet a, 1888. By John Tebbutt.

(*Communicated by A. A. Common.*)

Intelligence of the discovery of this comet at the Cape of Good Hope reached my observatory about noon on February 23, but the weather, which up to that time had been fine, suddenly became cloudy. I have observed the comet with the 8-inch equatorial and filar micrometer on every clear morning since that date. The nucleus is small and brilliant, and admits of precise observation. In consequence of the Moon's presence the comet is not a conspicuous object to the unassisted eye, its tail being only two or three degrees in length. By the mail now going out I forward you the following five positions. They depend on well-determined stars, but unfortunately in some instances the comparison intervals were large. The positions for the first two dates are corrected for refraction, but this correction, which cannot in any case exceed a second of arc, has not yet been applied to the differential results for the remaining dates.

1888.	Windsor Mean Time. d h m s	Comet's Apparent R.A. h m s	Comet's Apparent N.P.D. ° ′ ″	No. of Comps.	Comp. Star.
Feb.	27 16 35 34	20 2 10·75	...	17	1
	27 16 35 34	20 2 10·93	134 20 28·2	17	2
	28 16 34 30	20 6 53·64	132 52 32·8	4	3
March	2 17 9 9	20 20 13·76	128 21 26·4	3	4
	3 16 42 37	20 24 18·10	126 52 7·3	5	5
	3 16 42 37	20 24 17·92	126 52 6·9	5	6
	4 16 35 54	20 28 18·55	125 21 6·3	5	7

Mean Places of the Comparison Stars for 1888·0, *with the Reductions.*

Star.	R.A. h m s	N.P.D. ° ′ ″	Reductions. s ″	Authority for Mean Place.
1	20 1 38·82	134 14 28·6	−2·00 −6·0	Stone, 10799.
2	20 2 18·07	134 13 12·6	−2·01 −6·0	Stone, 10803.
3	20 4 41·78	133 6 30·5	−1·95 −5·7	Stone, 10820.
4	20 27 37·71	128 28 18·5	−1·85 −3·6	Stone, 10965.
5	20 9 6·17	126 47 39·2	−1·69 −4·5	Stone, 10840.
6	20 14 25·88	126 57 42·9	−1·72 −4·2	Cordoba Zone, 22, 55.
7	20 16 33·76	125 29 15·3	−1·67 −3·8	Stone, 10897.

Windsor, N. S. Wales:
1888, *March* 6.

On the Difference of Longitude between Mr. Tebbutt's Observatory, Windsor, New South Wales, and the Government Observatories at Sydney and Melbourne. By John Tebbutt.

On a single evening both in 1865 and 1878 the difference of longitude between my observatory and the Sydney Observatory was determined by telegraphic signals, the results being respectively $1^m\ 30^s{\cdot}04$ and $1^m\ 28^s{\cdot}83$. The time at Windsor for both these provisional determinations was derived from observations with a 2-inch transit instrument, and the preference was given to the latter result. As the longitude of Windsor was determined with great precision in 1884, by Dr. Auwers, from a long list of lunar occultations of stars, it was thought advisable in 1885 to redetermine the difference of longitude with all possible accuracy, inasmuch as more improved means existed here for the determination of the local time. It was therefore arranged to exchange telegraphic signals on three evenings in May 1885. As my observatory was not itself telegraphically connected with the Sydney Observatory, a mean-time chronometer had to be carried to the local telegraph office, distant about half a mile, for the transmission and reception of the signals. Signals were sent by hand to Syndey at every tenth second of the chronometer and recorded there on the transit-clock chronograph. It was arranged to receive seconds-signals from the Sydney clock, and to compare them with the chronometer by the method of coincidence of beats, but owing to the length and indefiniteness of the signals the attempt did not succeed. On the last evening signals were sent by hand from Sydney at every tenth second, being recorded there on the chronograph and compared at Windsor with the mean-time chronometer. In the autumn of last year it was suggested by Professor Harkness, of Washington, that the longitude from both Sydney and Melbourne should be determined with all possible care. During the winter several series of signals were accordingly exchanged between Windsor and the two observatories. The signals from Windsor were sent by hand from the local telegraph office at every tenth second by means of a mean-time chronometer, which was itself compared by coincidence of beats with the standard sidereal chronometer of my observatory both immediately before and after the exchange of signals, the latter timekeeper being regulated by the observation of a group of stars both shortly before and after the signals. The signals were recorded on the transit-clock chronograph at Sydney or Melbourne. The signals received at Windsor were sent at every second by the Sydney or Melbourne clock for the space of fifteen or twenty minutes with a break at the end of every minute, and compared with the mean-time chronometer by the method of coincidence of beats. On several occasions I also made trips to Sydney by railway in order to compare a mean-time chronometer with my standard

sidereal chronometer and the Sydney transit-clock. The comparisons of the chronometers were made by watching for the coincidence of beats, and those of the mean-time chronometer and the clock either by this method or by signals with the observing key recorded on the clock chronograph. As the mean-time chronometer was usually absent from my observatory only about twelve, and never more than twenty-four hours, the results from the transportation of the chronometer ought to be fairly good. The personal equation between Mr. Lenehan and myself was obtained from three evenings' observations at the Sydney Observatory. There has been no opportunity for determining that between Mr. White and myself. It appears that some years ago the Lenehan-White was found to be $+0^{s}\cdot12$, and this, combined with the value Tebbutt-Lenehan $+0^{s}\cdot06$, gives $+0^{s}\cdot18$ as a probable approximate value for Tebbutt-White.

With the foregoing brief explanation of the method adopted in the determination of the differences of longitude I now submit the following results of my investigation, and I trust to be able in the course of a short time to publish in a separate form the details of the work.

Difference of Longitude, Sydney–Windsor, from Telegraph Signals.

Date.		Signals.	Coincidences.	Windsor to Sydney.	Sydney to Windsor.
				m s	m s
1885, May	28	35	...	1 29·29	...
	28	17	...	1 29·24	...
	29	22	...	1 29·33	...
	29	35	...	1 29·34	...
	29	37	...	1 29·36	...
	30	42	...	1 29·32	...
	30	29	...	1 29·31	...
	30	37	...	...	1 29·34*
1887, June	8	21	...	1 29·37	...
	8	...	4	...	1 29·36
July	7	22	...	1 29·39	...
	7	...	5	...	1 29·36
	7	...	5	...	29·39
	7	22	...	1 29·28	...
Mean of all, with equal weights			...	1 29·32	1 29·36
Personal equation, T.–L.			...	+0·06	+0·03
Difference of longitude			...	1 29·38	1 29·39
					Mean = 1 29·39

* This difference was obtained by estimating the fractions of the half-seconds of the chronometer corresponding to the Sydney signals.

Difference of Longitude, Sydney–Windsor, from the Transportation of the Chronometer.

Date.	Key Signals.	Coincidences.	Difference of Longitude from Observer's key and chronograph. m s	Coincidence of beats. m s
1887, May 13	...	13	...	1 29·47
20	...	10	...	1 29·48
June 3	...	9	...	1 29·21
July 8	...	10	...	1 29·38
20	21	...	1 29·40	...
20	22	...	1 29·38	...
20	...	6	...	1 29·45
Nov. 24	18	...	1 29·75	...
24	19	...	1 29·70	...
24	...	5	...	1 29·72
Dec. 14	21	...	1 29·27	...
14	14	...	1 29·27	...
14	...	5	...	1 29·28
Mean of all, with equal weights		...	1 29·46	1 29·43
Personal equation, T.–L.		...	+0·06	+0·03
Difference of longitude		...	1 29·52	1 29·46
				Mean = 1 29·49

Difference of Longitude, Windsor–Melbourne, from Telegraphic Signals.

Date.	Signals.	Coincidences.	Windsor to Melbourne. m s	Melbourne to Windsor. m s
1887, June 13	22	...	23 25·86	...
13	...	4	...	23 25·96
13	10	...	23 25·88	...
15	22	...	23 26·05	...
15	...	3	...	23 26·08
15	...	4	...	23 26·22
15	22	...	23 26·09	...
23	22	...	23 26·00	...
23	...	5	...	23 26·19
23	22	...	23 26·05	...
Aug. 15	19	...	23 25·87	...
15	...	8	...	23 26·18
15	19	...	23 25·92	...
Mean of all with equal weights		...	23 25·97	23 26·13
Correction for assumed personal equation, T.–W.			−0·18	−0·18
Difference of longitude ...		...	23 25·79	23 25·95
				Mean = 23 25·87

It will be seen that the sum of the telegraphic mean differences in the preceding tables is $24^m\ 55^s{\cdot}26$, which is less than the result obtained directly between Sydney and Melbourne, and published in the "Report on the Telegraphic Determination of Australian Longitudes," by $0^s{\cdot}14$.

I may add that I have recently made a trigonometrical connection between my transit instrument and the north terminal of the Government base-line, about three miles nearly due west of my observatory. As the terminal could not be seen from the observatory, the position of an intermediate well-defined object was determined from bases at the observatory and the terminal. The chief officer of the Trigonometrical Survey here gives the following as the position of the terminal:

Longitude west of Sydney Observatory $= 1^m\ 42^s{\cdot}73$

Geographical latitude $= -33°\ 35'\ 58''{\cdot}07$

The differences of longitude and latitude between my transit instrument and the terminal as deduced trigonometrically are:

Longitude of terminal west $= 12^s{\cdot}96$

Latitude of terminal north $= 32''{\cdot}41$

A comparison of these results gives $1^m\ 29^s{\cdot}77$ as the longitude of my transit instrument west of the Sydney transit-circle. This is somewhat larger than the value obtained from the exchange of time signals with Sydney. Again adopting the above latitude of the terminal, I get $-33°\ 36'\ 30''{\cdot}48$ as the latitude of my transit instrument, which differs only $0''{\cdot}3$ from the value obtained directly from prime vertical observations in 1881. The trigonometrical work was performed with an ordinary steel tape and a common theodolite reading only to minutes of arc. The two triangles formed were ill-conditioned, but I nevertheless think the work was sufficiently accurate to give the difference of longitude to $0^s{\cdot}01$ and that of latitude to $0''{\cdot}1$.

Private Observatory, Windsor, N. S. Wales:
1888, *February* 24.

Erratum in Mr. Bryant's Paper, vol. xlviii. page 96.

The R.A. of Star No. 16 should be $13^h\ 26^m\ 47^s$ instead of $13^h\ 25^m\ 47^s$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. MAY 11, 1888. No. 7

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Thomas Dallmeyer, 19 Bloomsbury Street, W.C.;
Alfred Robert Johnson, M.A., St. John's College, Cambridge;
Reginald Carter Nelson, 19 Roker Terrace, Sunderland;
Sir Henry Thompson, M.B., 35 Wimpole Street, W.; and
John Walther, M.D., C.M. Edin., West House, Eastbourne,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended :—

T. Bolton, Calcutta (proposed by Robert Wigglesworth);
Andrew Claude de la Cherois Crommelin, B.A., Trinity College, Cambridge (proposed by Lieut.-Col. G. L. Tupman);
Arthur Herbert Leahy, M.A., Pembroke College, Cambridge (proposed by H. H. Turner); and
Samuel Maitland Baird Gemmill, 9 Gower Street, Kelvinside, Glasgow (proposed by the Rev. A. Henderson).

Regulations for the Library.

The works in the Library are available for the use of the Fellows, with the exception of the following, which may not be taken out without special permission of the Council :—

Manuscripts.
Original drawings and photographs.
Printed books of earlier date than 1500.
Maps and charts.

Royal Society Catalogue of Scientific papers.
Dictionaries.
Nautical Almanac
Connaissance des Temps
Berliner Astronomisches Jahrbuch
Washington Ephemeris
British Association Catalogue } except duplicates.
Lalande's Catalogue
Lacaille's Catalogue
Stone's Cape Catalogue
Gould's Catalogues

Total Solar Eclipse Committee.

At a meeting of the above Committee, appointed by the Council of the R.A.S., the following resolution was passed :—

That the Council be requested to move the President to notify to the Fellows generally the constitution of this Committee, and to mention its objects of—

(1) Bringing into communication with each other gentlemen willing to observe eclipses.

(2) Becoming a centre of information for intending observers.

Note on the Total Solar Eclipse of 1889, *December* 21–22.

By J. R. Hind, LL.D., F.R.S.

In the second of the two total eclipses of the Sun occurring in the year 1889, although the track of the central line where duration of totality is longest is across the Atlantic, observations will be obtainable at three points in its course where the Sun will have an altitude of more than ten degrees.

First, at the southern extremity of the island of Trinidad, at Point Icacos, where the circumstances are :

	h	m	s	
Totality begins Dec. 21 at	19	6	27	local M.T.
Duration of totality		1	46	

Sun's altitude, 12°.

Next, at Cayenne, in French Guiana, where

	h	m	s	
Totality begins Dec. 21 at	19	51	23	local M.T.
Duration of totality		2	3	

Sun's altitude, 24°.

Again, where the central line meets the west coast of Africa, in about 13° 20′ east longitude, and 9° 42′ south latitude. At this point

	h	m	s	
Totality begins Dec. 22 at	2	56	3	local M.T.
Duration of totality		3	12	

Sun's altitude, 46°.

For any point near this the Greenwich mean time of beginning and ending of totality may be found from the formulæ,

$$\cos\omega = +8{\cdot}9188 - [1{\cdot}93737]\sin l + [1{\cdot}57729]\cos l\,.\,\cos(\lambda + 217^\circ\ 36'{\cdot}6)$$

$$t = 0^h\ 19^m\ 45^s{\cdot}5 \mp [1{\cdot}98325]\sin\omega + [2{\cdot}59376]\sin l - [3{\cdot}95966]\cos l\,.\,\cos(\lambda + 121^\circ\ 32'{\cdot}4),$$

where l is the *geocentric* latitude, λ the longitude from Greenwich taken *positively*, and the quantities within square brackets are the logarithms of seconds of time.

The central line on entering Africa runs through the following points:

Greenwich Mean Time.		Longitude E.		Latitude S.	
h	m	°	′	°	′
2	4	13	10·3	9	45·1
2	5	13	41·3	9	34·8
2	6	14	12·7	9	24·2
2	7	14	44·5	9	13·4
2	8	15	16·9	9	2·2

Remarks on Sir George Airy's "Numerical Lunar Theory."

By Professor J. C. Adams, M.A., &c.

In the Report of the Council on the subject of Sir George Airy's "Numerical Lunar Theory," it has been explained that the large discordances which have been found by the author to result from the substitution of the values of the Moon's coordinates, as found by Delaunay, in the differential equations of motion, are caused by the large errors of Delaunay's coefficients of parallax, which Sir George has employed. It may be useful and not uninteresting to give on this subject some additional details. In the first place it will be well to prevent a possible misapprehension. In speaking of the errors of Delaunay's coefficients it is not intended to imply that there is any mistake in Delaunay's *theory*. The terms of the analytical expression for the Moon's parallax which Delaunay gives are all correct, but they only extend to the fifth order of small quantities, and are therefore not nearly precise enough to be used for the purpose to which the expression for the parallax is applied by Sir George

Airy. Delaunay intended this value of the parallax to be employed merely in reducing the apparent place of the Moon to its place as seen from the Earth's centre, and for this purpose the value is perhaps sufficiently accurate.

If the several transformations of the elements given by Delaunay in his great work had been applied to the analytical expression for the reciprocal of the radius vector, and if Delaunay had carried the developments to the same extent as he had done in the case of the Moon's longitude and latitude, the theory would have been quite competent to give the third coordinate with the same degree of precision as had been attained in the case of the two other coordinates.

The following table, which is reduced from the table given in pp. 398, 399, of vol. xliii. of the *Monthly Notices*, R.A.S., shows the proportional values of the coefficients of parallax as found by me, mainly after Pontécoulant, when compared with those employed by Sir George Airy after Delaunay.

Argt.	My Coefficient.	Delaunay's.
o	10000000,	10000000,
l	544989. 3	545145, 6
$2D-l$	100236, 0	99822. 4
$2D$	82493, 6	82329, 2
$2l$	29716. 6	29796. 4
$2D+l$	9029. 0	8950. 8
$2D-S$	5595. 6	5482, 2
$2D-l-S$	4234. 0	4243. 1
$l-S$	3380. 7	3074. 5
D	− 2773. 0	− 2739. 9
$l+S$	− 2770. 0	− 2664. 0
$2l'-l$	− 2074. 6	− 2068, 25
$3l'$	1835. 0	1844. 7
$4D-l$	1753. 2	1458, 2
S	− 1168. 8	− 1248, 4
$2D-l-S$	− 675. 0	− 1107, 0
$2D-S$	− 894. 1	− 957, 1
$4D-2l'$	1087. 0	906, 9
$2D-2l'$	− 897. 05	− 809, 3
$2D-2l'$	821. 0	790, 9
$2D+l-S$	648. 7	574. 7
$4D$	759. 7	572, 6
$D-S$	423. 7	440, 3
$2D-2l'$	− 309. 7	− 319. 0
$2l'-S$	359. 4	300, 9

Argt.	My Coefficient.	Delaunay's.
$2D-3l$	− 338, 95	− 295, 7
$D+l$	− 309, 7	− 283, 7
$2l+S$	− 292, 2	− 267, 9
$2D-2f-l$	− 251, 3	− 238, 4
$2D-2S$	260, 05	222, 0
$2D-2f+l$	− 140, 25	− 146, 4
$2D-l-2S$	146, 1	132, 6
$4l$	119, 8	121, 0
$2D+l+S$	− 137, 3	− 117, 2
$4D-l-S$	184, 1	86, 8
$3D-l$	− 105, 2	− 58, 1
$4D+l$	93, 5	54, 05
$2D+3l$	51, 2	51,
$4D-2l-S$	87, 7	46, 5
$3D$	14, 6	46, 2
$2D+2f-2l$	− 42, 6	− 43,
$D+l+S$	38, 9	38, 9
$l-2S$	38, 3	38, 3
$2D-l+2S$	− 37, 4	− 37, 4
$2D-2l-S$	− 37, 1	− 37, 1

This table shows at a glance how great the errors of Delaunay's coefficients of parallax, when reduced to the form in which they are employed by Sir George Airy, in many cases really are. Hence the discordances which he met with in the results of the substitutions should occasion no surprise. In the Introduction to the "Numerical Lunar Theory," p 4, line 20, it is stated through inadvertence that the factor which Sir George Airy calls M is a quantity "depending on the proportion of the masses of the Earth and Moon." This is not the case however, since M is simply the ratio of the sum of the actual masses of the Earth and Moon to the sum of the masses which would be required to make the Moon describe an undisturbed orbit about the Earth in which the periodic time and the mean parallax were the same as in the actual orbit.

The theoretical value of M is simply expressed as the *cube* of the constant term in Delaunay's value of $\frac{a}{r}$. This value is given analytically in p. 802 or p. 914 of the second volume of Delaunay's Theory, but only to the fifth order of small quantities, which is not accurate enough. The development of the constant term of $\frac{a}{r}$ has been carried by me to a much greater extent at p. 472 of vol. xxxviii. of the *Monthly Notices*. Turning this expres-

sion into numbers, and cubing it, we find the value of M to be 1·0027259, which agrees very closely with the value found by Sir George Airy by comparing the constant terms on the two sides of his equation (10).

The other two ways of finding M proposed by Sir George in p. 76 of his Theory, viz. by comparing the quantities on the two sides of the equations (10) and (12), corresponding to the arguments 2 and 301 respectively, are not satisfactory, as the results will be affected by errors in the theoretical determinations of the mean motions of the Moon's perigee and node respectively.

The multiplier M, representing the sum of the masses of the Earth and Moon, must be employed wherever the mutual attraction of these two bodies comes in question. In Sir George Airy's note at p. 254 of the March number of the *Monthly Notices*, he calls M the coefficient of a *solar* term, but this is plainly a mistake. I should mention that I have already communicated the substance of this paper to Sir George Airy himself.

The Positions for 1750·0 *and Proper Motions of* 154 *Stars south of* −29° *declination deduced from a revision of Powalky's Reduction of the Star Places of Lacaille's Astronomiæ Fundamenta.* By A. M. W. Downing, M.A.

In the report of the Superintendent of the U.S. Coast and Geodetic Survey for the year ending June 1882, the late Dr. C. R. Powalky published "a new reduction of Lacaille's observations, made at the Cape of Good Hope and at Paris between 1749 and 1757, and given in his *Astronomiæ Fundamenta*, together with a comparison of the results with the Bradley-Bessel *Fundamenta*; also a catalogue of the places of 150 stars south of declination −30°, for the epochs 1750 and 1830." Powalky's catalogue thus depends on the star places of Bessel's *Fundamenta*, that is to say, the assumed right ascensions of the stars used for determination of clock error are those of the *Tabulæ Regiomontanæ* or of the *Fundamenta*, and systematic corrections to Lacaille's declinations have been determined by comparing them with the same authorities. It is the object of the present paper to deduce the necessary corrections to Powalky's places of the stars observed at the Cape, so as to make them depend on Auwers' re-reduction of Bradley, and to determine the proper motions resulting from a comparison of these corrected places with the mean for the epoch 1875 of Stone's Cape Catalogue, and Gould's Argentine General Catalogue. The various processes of reduction are not very clearly explained by Powalky, and on my writing to Professor Peters, of Clinton (who examined and reported on the paper), to ask if he could supply me with any further information, he had the great kindness to cause a search

for Powalky's MSS. to be made, a search which unfortunately proved unsuccessful. It was necessary therefore to go through some of the computations in order to ascertain how the star places used in the reductions had been deduced from Bessel's places, and as the result of this examination it appeared that the apparent places of the stars contained in the *Tabulæ Regiomontanæ*, which were used for clock error, were taken without alteration from that work (with the exception of *Sirius*, the apparent places of which were corrected for orbital motion as determined by Auwers), and that the apparent places of stars taken from the *Fundamenta* were brought back from 1755 with the annual precessions of the *Fundamenta*, without proper motion, but with "star corrections" computed from the modern elements. It has been assumed, therefore, that Powalky's "star corrections" are correct throughout (he states that the "day constants" for 1750–1757 were taken from Struve's *Tabulæ Quantitatum Besselianarum pro annis* 1750–1840), and that in bringing back the places from the *Fundamenta* he has used the precessions of the *Fundamenta*, omitting proper motions. In revising the assumed right ascensions of "clock" stars (which as well as the southern stars were observed by Lacaille at the Cape by the method of equal altitudes, using an iron 3-foot quadrant in connection with a $3\frac{1}{2}$-foot telescope and a clock of Le Roy), it was therefore necessary to compute "star corrections" for *Sirius* and for the other *Tabulæ Regiomontanæ* stars for each day on which they were observed, using the *Tabulæ Quantitatum Besselianarum pro annis* 1750–1840, and Stone's "Tables for Constants of Star Reductions" adapted to the epoch. The proper motions were, of course, taken from Auwers' Bradley, and the places of *Sirius* and *Procyon* further corrected for orbital motion in accordance with the elements determined by the same astronomer (*Publ. Ast. Ges.* No. vii., and *Ast. Nach.* No. 1373). The apparent places of the *Fundamenta* stars as given by Powalky were corrected for proper motion, difference between Bessel's and Struve's precessions, and difference between Bessel's and Auwers' reduction of Bradley. The clock errors deduced from observations of the Sun, for which the Hansen-Olufsen Solar Tables were used, have been retained unaltered. From the clock errors thus corrected the revised right ascensions of the southern stars were determined. With but two or three exceptions these were observed on one day only, and it is difficult to form an estimate as to the probable errors of the positions; from forty observations of *Sirius*, however, made on days when there was a fair independent determination of clock error, the mean right ascension for 1751·0 is $6^h\ 34^m\ 10^s{\cdot}626$, with probable error of a single determination $\pm 0^s{\cdot}182$, which should not differ much from the probable error of a Catalogue place. The maximum correction applicable to the right ascension of a southern star as reduced by Powalky is $0^s{\cdot}15$.

Observations of zenith distance were made by Lacaille at the Cape with

I. Sextant with 6-foot telescope,
II Sextant with 5-foot telescope,
III. Sector,

some details of the construction of which are given by Powalky, pp. 470, 471.

For the latitude of Lacaille's observatory at the Cape, Powalky's value ($-33^\circ\ 55'\ 15''\cdot8$) has been used. It is stated on p. 471 that the refractions have been computed from the Pulkowa tables, with "corrections for mean temperature (from Dove's tables) and barometer."

Corrections to the *Fundamenta* declinations, as given by Powalky, of the Bradley stars observed by Lacaille at the Cape have been determined in the same way as for the right ascensions, and corrections to Lacaille's three series of declinations, of the form $x \sin\delta + y \cos\delta$, deduced by the method of least squares from the comparison of Lacaille's places of these stars with the standard places, in combination with the observations of circumpolar stars observed above and below the pole. The three series of corrections, compared with the corresponding ones deduced by Powalky, are:

I.	α.	$+6''\cdot9 \sin\delta$	$+3''\cdot4 \cos\delta$
	β.	$+6\cdot04 \sin\delta$	$+3\cdot05 \cos\delta$
II.	α.	$+8\cdot33 \sin\delta$	$+4\cdot45 \cos\delta$
	β.	$+5\cdot79 \sin\delta$	$+4\cdot43 \cos\delta$
III.	α.	$+20\cdot5 \sin\delta$	$+11\cdot5 \cos\delta$
	β.	$+18\cdot29 \sin\delta$	$+10\cdot91 \cos\delta$

The figures I. II. and III. refer to the three series of declinations observed by Lacaille with his different instruments described above, and α and β are the corrections deduced by Powalky and in the present investigation respectively. The differences found between these may to some extent be due to difference of treatment. In the present investigation, for convenience of computation, the stars have been combined in groups, the correction deduced from each star place being given equal weight, independently of the number of observations on which it depends, and in I. and II. the groups have been given weights equal to the number of stars included in each, whilst in III., as the distribution of groups is unfavourable, each group has been given equal weight. It is not quite clear what course has been followed by Powalky in this part of the work. The application of these corrections gives the final catalogue declinations, which in general depend on observations made with one instrument only, but in those cases (there are ten of them) in which more

than one instrument has been used, the agreement is satisfactory, the average discordance being $2''\cdot8$, and the maximum discordance $5''\cdot7$. In combining observations made with different instruments, half weight has been given to II. From Powalky's paper, p. 475, where he gives the separate re-reduced observations of zenith distance of *α Virginis*, it appears that the probable error of a single declination observed at the Cape with the sextant (principal telescope) is $\pm3''\cdot2$, and with the sector is $\pm1''\cdot4$; the corrections of the form $x\sin\delta+y\cos\delta$ are much more satisfactorily determined for the former than for the latter, and it appeared preferable, therefore, to give the results derived from these two instruments equal weight when combining them. Powalky gives no data for determining the probable error of a declination observed with the smaller telescope on the sextant. The declinations in the Catalogue depend generally on five or six observations.

For further details of the observations and their reduction the reader is referred to Powalky's paper.

A catalogue of the places of 154 stars south of declination $-29°$ for the epoch 1750·0 having been thus formed, precessions for that epoch were computed by the help of Stone's "Tables for Constants of Star Reductions" before mentioned. With these precessions and their secular variations, deduced from comparing them with the precessions given in the Cape Catalogue for 1850, the places of the stars were brought up to 1812·5, the middle epoch between 1750·0 and 1875·0, and the precessions again computed for 1812·5. We thus have precessions for three equi-distant epochs, 1750·0, 1812·5 and 1875·0 (the latter being taken from Gould's Catalogue), and therefore the mean annual precession for the interval 1750–1875

$$=\tfrac{1}{6}(p_1+4p_2+p_3),$$

which is accurate to the fourth power of the time.

By means of the mean annual precessions computed from this formula, Lacaille's places have been brought up to 1875·0, and compared with the mean of Stone's Cape Catalogue (brought back from 1880 with the proper motions of that Catalogue), and Gould's Argentine General Catalogue, and thus the proper motions given in the following catalogue have been determined.

The same method has been followed for all the stars contained in the catalogue except *τ Octantis* (Dec. $1750=88°\ 50'$), for which the rigorous trigonometrical formulæ have been used.

Where a star in the catalogue is designated by Lacaille's number, the reference is to the number in Lacaille's Zone Catalogue of 9766 stars. The approximate places of stars observed in one element only have been taken from the same catalogue.

In the case of *α Centauri* the common proper motion has been found by comparing the mean of the places of the two components for 1750, brought up to 1875, with the mean of their places for 1875.

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
ζ Toucani	0 6 52·12	51·77	+2·9783	+2·9406	+0·268	−66 20 45·2	52·0	+20·057	+20·041	+1·18
β Hydri	0 12 11·02	51·73	2·7152	2·6551	+0·709	78 39 50·2	51·9	20·037	20·017	+0·31
α Phœnicis	0 13 51·60	51·77	2·9926	2·9776	+0·018	43 39 57·6	51·8	20·029	20·005	−0·40
λ Phœnicis	0 19 17·30	52·86	2·9349	2·9168	+0·008	50 11 22 2	52·1	19·995	19 965	+0·03
β¹ Toucani	0 19 58·25	51·77	2·8275	2·7972	−0·002	64 20 21·2	51·6	19·989	19·960	−0·02
ξ Phœnicis	0 30 19	...	...	...	...	57 52 57·8	52·2	19·889	19·850	+0·12
η Phœnicis	0 32 1·66	51·85	2·7618	2·7402	−0·003	58 49 30	...	...	...	...
λ Hydri	0 39 50·39	51·77	2·1215	2·0967	+0·017	76 17 16·8	51·9	19·763	19·724	−0·04
β Phœnicis	0 54 52·31	51·70	2·7167	2·7047	−0·003	48 3 48·0	51·8	19·493	19·428	+0·01
ζ Phœnicis	0 57 48	...	...	...	...	56 35 18·7	51·9	19·430	19·366	+0·05
γ Phœnicis	1 17 28·18	51·70	2·6322	2·6239	0·000	44 36 27·2	51·7	18·930	18·844	−0·17
δ Phœnicis	1 20 47·92	51·70	2·5118	2·5025	+0 016	50 22 48·2	51·7	18·831	18·746	+0 19
α Eridani	1 28 22·40	51·73	2 2484	2·2397	+0·008	58 30 52·9	52·2	18·592	18·509	−0 02
χ Eridani	1 46 12·98	52·86	2·2802	2·2744	+0·067	52 51 46·2	52·3	17·949	17·851	+0·34
α Hydri	1 50 52·93	51·77	1·8594	1·8576	+0·038	62 47 36·2	52·3	17·762	17·678	+0·03
δ Hydri	2 17 23·53	51·75	1·0183	1·0375	−0·012	69 48 5·7	52·0	16·567	16·509	−0·01
κ Hydri	2 21 38·79	51·85	+0·2208	+0·2732	−0 037	74 46 46·0	52·0	16 354	16·336	0·00
μ Hydri	2 37 47·14	51·85	−1·8477	−1·6640	+0·029	80 11 38·9	52·0	15·495	15·592	−0·05
θ Eridani	2 48 47·01	51·77	+2·2799	+2·2796	−0·006	41 19 9·3	51·9	14·866	14·721	+0·05
12 Eridani	3 1 27·42	51·77	+2·5205	+2·5211	+0·025	−29 59 13·1	52·0	+14·098	+13·929	+0·66

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
Lacaille 1244	3 39 22·69	51·92	+2·2029	+2·2045	+0·007	−38 23 58·4	52·0	+11·553	+11·385	+0·03
Lacaille 1253	3 41 10·44	51·94	+0·6456	+0·6647	+0·039	65 35 57·8	52·0	11·425	11·373	+0·12
γ Hydri	3 51 26·85	51·85	−1·1572	−1·0872	+0·008	74 59 54·4	52·0	10·674	10·757	+0·09
υ^4 Eridani	4 8 27·c3	51·85	+2·2595	+2·2615	+0·001	34 25 26·1	52·0	9·385	9·200	+0·01
α Reticuli	4 11 16·39	51·85	0·7239	0·7378	+0·004	63 6 14·1	52·0	9·167	9·105	+0·02
δ Cœli	4 23 11·95	51·92	1·8280	1·8311	−0·004	45 30 11·6	52·0	8·225	8·071	0·00
υ^7 Eridani	4 25 50	...	...	...	...	31 5 25·8	52·0	8·015	7·817	−0·01
α Doradûs	4 28 36 83	51·82	+1·2711	+1·2774	+0·010	55 34 29·2	52·1	7·790	7 681	+0·11
δ Mensæ	4 35 43·74	51·92	−4 6121	−4·4399	+0·005	80 46 13·8	52·0	7·213	7·594	+0·07
α Columbæ	5 30 36·35	51·94	+2·1674	+2·1690	−0·001	34 13 24·0	52.5	2·567	2·369	−0·02
β Doradûs	5 31 29·47	51·97	0·5027	0·5078	−0·003	62 39 29·6	52·1	2 490	2·443	+0·05
β Columbæ	5 42 9·68	51·92	+2·1051	+2·1068	+0·001	35 52 42·7	52·5	+1·560	+1·367	−0 06
ν Doradûs	6 10 21·74	51·98	−0·3732	−0·3742	−0·020	68 47 14·7	52·1	−0·907	−0·874	+0·04
ζ Canis Majoris	6 10 43	...	...	...	...	29 58 11·5	52·2	0·938	1·145	+0·01
3 Canis Majoris	6 12 59·31	51·94	+2·1916	+2·1929	−0·006	33 19 37·4	52·1	1·137	1·335	−0·03
α Argûs	6 18 24·34	51·74	1·3277	1·3285	+0·002	52 34 10·3	52·2	1·610	1·729	+0·04
ν Argûs	6 30 6·87	51·94	1·8335	1·8344	+0·001	42 59 30·7	52·2	2·629	2·795	+0·04
τ Argûs	6 43 43·77	51·98	1·4861	1·4861	+0·003	50 19 42·9	52·2	3·806	3·938	−0·04
α Pictoris	6 45 37·61	51·97	0·6368	0·6330	−0·018	61 40 40·5	52·2	3·969	4·025	+0·30
π Argûs	7 8 19·04	51·97	+2·1179	+2·1187	−0·001	−36 39 47·7	52·2	-5·893	−6·075	+0·01

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
δ Volantis	7 16 53·14	52·02	+0·0204	+0·0056	−0·004	−67 29 57·6	52·3	−6·606	−6·612	+0·01
σ Argûs	7 21 18·40	51·98	1·9078	1·9082	−0·009	42 48 30·5	52·2	6·970	7·130	+0·20
α Puppis	7 43 37·67	52·06	2·0621	2·0618	−0·001	39 56 39·4	52·2	8·767	8·934	+0·01
ζ Argûs	7 54 48·12	52·06	2·1090	2·1098	−0·003	39 18 44·0	51·3	9·636	9·802	+0·02
γ Argûs	8 1 49·91	52·03	1·8499	1·8500	−0·002	46 36 40·8	52·2	10·171	10·314	+0·01
ε Argûs	8 17 21·38	52·06	+1·2521	+1·2467	−0·002	58 42 52·2	52·2	11·318	11·409	+0·08
α Chamæleontis	8 24 34·27	52·09	−1·3021	−1·3873	+0·020	76 7 12·7	52·3	11·834	11·732	+0·11
o Argûs	8 33 7·38	52·03	+1·7236	+1·7231	0·000	52 2 36·9	52·2	12·431	12·551	+0·02
δ Argûs	8 37 48·18	52·09	1·6584	1·6573	−0·002	53 48 8·3	52·3	12·750	12·863	−0·07
α Volantis	8 58 26·83	52·09	0·9896	0·9768	−0·006	65 24 10·2	52·3	14·092	14·152	−0·09
λ Argûs	8 58 48·54	52·03	2·2005	2·2032	0·000	42 26 9·2	52·3	14·114	14·254	+0·06
G Carinæ	9 4 19·77	52·12	0·2811	0·2451	−0·018	71 35 49·1	52·3	14·454	14·466	−0·02
β Argûs	9 10 20·94	52·08	0·7574	0·7364	−0·031	68 41 25·5	52·3	14·815	14·857	+0·10
ι Argûs	9 10 23·84	52·12	1·6130	1·6117	−0·005	58 14 8·8	52·4	14·817	14·913	+0·06
κ Argûs	9 14 23·31	52·09	+1·8543	+1·8558	−0·005	53 57 7·6	52·2	15·051	15·158	+0·03
ζ Octantis	9 28 9 32	52·12	−5·6728	−6 4616	−0·104	84 37 26·1	52·3	15·820	15·469	+0·03
υ Argûs	9 40 50·80	52·06	+1·5106	+1·5078	−0·006	63 55 6·6	52·4	16·479	16·553	+0·02
φ Argûs	9 48 7·13	52·09	2·0901	2·0956	−0·004	53 23 14·6	52·3	16·833	16·933	+0 06
ω Argûs	10 7 46·87	52·09	1·4478	1·4447	−0·012	68 48 5·6	52·3	17·708	17·764	+0·02
I Carinæ.	10 19 22·00	52·12	+1·2359	+1·2245	−0·003	−72 45 46·5	52·3	−18·162	−18·205	−0·02

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0	Epoch 1700+.	Annual Precession 1750·0	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
p Carinæ	10 23 11·76	52·09	+2·1044	+2·1141	−0·007	−60 24 22·4	52·3	−18·302	−18·375	+0·04
θ Argûs	10 34 6·05	52·15	2·1050	2·1166	−0·004	63 5 24·5	52·2	18·672	18·737	+0·02
η Argûs	10 35 25·72	52·09	2·2863	2·2992	−0·001	58 22 39·6	52·3	18·715	18·784	+0·06
μ Argûs	10 36 4·51	52·15	2·5360	2·5474	+0·007	48 6 24·0	52·3	18·735	18·812	−0·01
δ^2 Chamæleontis	10 43 11·65	52·15	0·7587	0·7089	−0·039	79 13 21·6	52·3	18·949	18·966	0·00
η Octantis	11 0 15·98	52·12	0·1586	0·0072	−0·070	83 14 49·7	52·4	19·387	19·383	−0·04
Lacaille 4779	11 20 45	...	...	...	...	30 28 35·5	51·7	19·772	19·811	+0·05
λ Centauri	11 24 23·10	52·09	2·6863	2·7125	−0·005	61 38 21·1	52·1	19·824	19·855	+0·01
π^1 Chamæleontis	11 27 9·91	52·15	2·3805	2·4188	−0·040	74 30 49·8	52·4	19·860	19·884	−0·02
ϵ Chamæleontis	11 47 37·45	52·33	2·7614	2·8284	−0·034	76 49 43·5	51·5	20·035	20·043	−0·03
κ Chamæleontis	11 52 16·02	52·26	2·8999	2·9656	−0·053	75 7 46·4	52·4	20·054	20·056	+0·04
λ Chamæleontis	11 55 2·33	52·26	2·9691	3·0329	−0·040	73 58 35·5	52·4	20·060	20·060	+0·04
δ Centauri	11 55 31·04	52·12	3·0394	3·0621	−0·004	49 19 45·8	51·9	20·061	20·060	0·00
ρ Centauri	11 58 42 94	52·26	3·0607	3·0849	−0·007	50 58 35·3	52·4	20·065	20·059	+0·02
δ Crucis	12 2 2·19	52·31	3·0885	3·1196	−0·007	57 21 30·6	52·3	20·064	20·055	+0·04
β Chamæleontis	12 4 16·77	52·29	3·1866	3·2864	−0·034	77 55 18·5	52·4	20·061	20·049	0·00
ϵ Crucis	12 8 2·81	52·29	3·1481	3·1828	−0·024	59 1 13·4	52·4	20·053	20·036	+0·17
α^1 Crucis	12 12 55·28	52·29	3·2100	3·2500	−0·015	61 42 47·5	52·3	20·033	20·010	+0·06
γ Crucis	12 17 27·59	52·29	3·2192	3·2514	+0·005	55 42 45·3	52·3	20·007	19·977	−0·20
γ Muscæ	12 17 54·18	52·31	+3·3689	+3·4359	−0·016	−70 44 53·7	52·3	−20·004	−19·972	−0·01

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
α Muscæ	12 22 34·65	52·31	+3·3915	+3·4498	−0·006	−67 45 15·7	52·4	−19·969	−19·929	0·00
γ Centauri	12 27 51·40	52·15	3·2474	3·2724	−0·020	47 34 58·8	51·5	19·917	19·874	0·00
β Muscæ	12 31 15·27	52·31	3·4929	3·5510	−0·008	66 44 5·8	52·3	19·879	19·828	0·00
β Crucis	12 33 18·28	52·29	3·3837	3·4211	−0·001	58 19 8·5	52·4	19·854	19·803	+0·05
δ Muscæ	12 45 29·45	52·31	3·8023	3·8816	+0·061	70 11 37·0	52·4	19·671	19·594	0·00
ι Centauri	13 6 37·99	51·40	3·3423	3·3606	−0·028	35 23 9·7	51·9	19·223	19·129	−0·06
ε Centauri	13 24 14·18	51·41	3·6892	3·7247	−0·007	52 11 1 3	51·5	18·725	18·596	−0·01
ν Centauri	13 34 37·82	52·26	3·5273	3·5503	−0·306	40 25 52·0	51·5	18·379	18·242	+0·03
μ Centauri	13 34 40·33	52·31	3·5403	3·5640	−0·001	41 13 3·0	51·5	18·378	18·240	+0·03
g Centauri	13 35 3·11	52·26	3·4225	3·4404	−0·004	33 11 29·2	52·5	18·364	18·231	−0·03
k Centauri	13 37 29·62	52·24	3·4114	3·4285	−0·010	31 44 34·8	52·5	18·276	18·141	0·00
ζ Centauri	13 40 5·20	51·41	3·6567	3·6852	−0·006	46 2 44·3	51·5	18·182	18·034	0·00
β Centauri	13 46 26·97	52·24	4·0731	4·1239	−0·009	59 9 2·2	52·5	17·940	17·764	−0·03
δ Octantis	13 50 1·14	52·31	7·7539	8·2939	−0·089	82 29 12·2	52·3	17·797	17·443	0·00
θ Centauri	13 52 3·99	51·41	3·5120	3·5314	−0·045	35 7 37·2	51·6	17·714	17·556	−0·50
ι Lupi	14 3 31·53	52·29	3·7539	3·7817	+0·003	44 53 33·6	51·5	17·220	17·037	+0·13
η Centauri	14 19 44·79	51·40	3·7368	3·7608	−0·002	41 2 34·3	51·5	16·449	16·247	−0·01
α Circini	14 22 39·07	51·41	4·6593	4·7272	−0·033	63 51 47·9	52·5	16·302	16·045	−0·24
α^1 Centauri	14 22 48·26	51·41	4·4103	4·4643	−0·482	59 47 26·1	52·5	16·295	16·052	+0·82
α^2 Centauri	14 22 49·97	51·41	+4·4106	+4·4644	−0·482	−59 47 9·9	52·5	−16·293	−16·050	+0·82

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
α Lupi	14 25 27·26	51·40	+3·8997	+3·9288	−0·007	−46 17 46·3	51·5	−16·158	−15·939	−0·01
β Lupi	14 42 16·56	51·41	3·8561	3·8805	−0·004	42 6 19·2	51·5	15·241	15·006	−0·07
κ Centauri	14 43 0 80	51·46	3·8311	3·8546	−0·002	41 4 50·3	51·5	15·200	14·965	−0·02
π Lupi	14 48 14·65	51·46	3·9996	4·0276	−0·009	46 3 4·0	51·5	14·897	14·645	−0·01
γ Trianguli Australis	14 56 0·32	51·41	5·3385	5·4246	−0·016	67 43 32·2	52·5	14·433	14·085	−0·02
δ Lupi	15 5 3·84	51·41	3·8729	3·8942	−0·002	39 43 13·8	51·5	13·872	13·609	0·00
ε Lupi	15 5 49·46	51·41	3 9987	4·0233	−0·002	43 46 0·9	51·6	13·822	13·552	−0·01
γ Lupi	15 18 34·58	51·41	3·9345	3·9553	0·000	40 18 9·5	51·5	12·993	12·713	−0 01
β Trianguli Australis	15 33 22·94	51·40	5·1424	5·1959	−0·029	62 37 34·6	52·5	11·978	11·594	−0·38
α Trianguli Australis	16 22 28·32	51·41	6·1665	6·2271	+0·002	68 31 24·5	52·5	8·283	7·764	−0 04
ε Scorpii	16 34 1·13	51·41	3·9035	3·9140	−0·050	33 48 41·1	52·1	7·353	7·018	−0·26
μ^1 Scorpii	16 34 59·60	51·46	4·0297	4·0415	−0·003	37 35 22·7	51·6	7·273	6·927	0·00
ζ^2 Scorpii	16 37 3·27	51·49	4·1924	4·2059	−0 013	41 54 5·7	51·6	7·104	6·744	−0·26
ζ Aræ	16 38 2·78	51·49	4·8973	4·9208	−0·012	55 33 36·4	52·1	7·023	6·600	−0 02
ϵ^1 Aræ	16 39 44·94	52·44	4·7218	4·7421	0·000	52 44 32·4	51·5	6·883	6·474	+0·05
η Scorpii	16 54 18·11	51·49	4·2613	4·2727	−0·001	42 52 44·6	51·6	5·673	5·299	−0·25
γ Aræ	17 4 25·58	51·49	5·0028	5·0196	−0·002	56 6 21·6	52·5	4·818	4·372	+0·04
β Aræ	17 4 35·22	51·49	4·9425	4·9587	−0·002	55 15 24·9	51·6	4·804	4·365	0·00
δ Aræ	17 8 36·91	51·49	+5·3690	+5·3886	−0·011	−60 26 4·6	52·5	−4·461	−3·981	−0·09

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
α Aræ	17 12 33·74	51·47	+4·6105	+4 6214	−0·004	−49 38 38·2	51·6	−4·123	−3·710	−0·03
υ Scorpii	17 13 47·91	51·52	4·0599	4·0667	−0·002	37 3 59·6	51·6	4·017	3·653	0·00
λ Scorpii	17 16 39·56	51·64	4·0561	4·0625	−0·001	36 53 32·2	51·6	3·772	3·406	+0·01
θ Scorpii	17 19 23·24	51·41	4·2896	4·2969	−0·001	42 48 28·8	51·6	3·537	3·151	+0·06
η Pavonis	17 21 16·51	51·49	5·8412	5·8603	−0·007	64 33 27·9	52·2	3·374	2·847	−0·10
κ Scorpii	17 25 13·17	51·49	4·1358	4·1414	−0 003	38 52 19·3	51·6	3·034	2·659	+0·05
ι¹ Scorpii	17 30 7·98	51·40	4·1827	4·1879	−0·007	39 59 54·4	51·5	2·607	2·227	0·00
γ¹ Sagittarii	17 49 3·68	51·52	3·8280	3·8296	−0·003	29 33 45·2	51·6	0·957	0 608	+0·02
γ² Sagittarii	17 49 45	...	...	...	...	30 23 53·5	51·6	−0·897	−0·546	−0·17
η Sagittarii	18 0 42·86	51·41	4·0709	4·0713	−0·013	36 48 25·8	51·6	+0·063	+0·433	−0·13
δ Sagittarii	18 4 58	...	...	...	...	29 54 18 0	51·6	0·435	0·785	−0·03
ε Sagittarii	18 7 34·91	51·41	3·9878	3·9875	−0·007	34 28 19·6	52·2	0·664	1·027	−0·13
α Telescopii	18 8 25·66	51·55	4·4577	4·4563	−0·004	46 4 21·8	51·7	0·738	1·145	−0·04
ζ Pavonis	18 13 43·08	52·44	7·0812	7·0653	−0·007	71 35 18·7	51·7	1·200	1·843	−0·18
ζ Sagittarii	18 46 41	...	...	...	...	30 12 35 6	51·6	4·059	4·399	+0·02
β¹ Sagittarii	19 4 36·57	51·59	4·3501	4·3389	0·000	44 53 48·3	51·7	5·582	5·962	−0·04
β² Sagittarii	19 5 5·92	51·59	4·3647	4·3533	+0·007	45 14 18·8	51·7	5·623	6·002	−0·06
α Sagittarii	19 6 30·83	51·59	4·1864	4·1766	+0·004	41 3 26·3	51·7	5·742	6·104	−0·09
ε Pavonis	19 31 11·41	51·55	+7·2393	+7·1435	+0·013	−73 31 24·1	51·7	+7·775	+8·372	−0·11

Star's Name.	Mean R.A. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in R.A.	Mean Dec. 1750·0.	Epoch 1700+.	Annual Precession 1750·0.	Annual Precession 1812·5.	Proper Motion in Dec.
	h m s		s	s	s	° ′ ″		″	″	″
δ Pavonis	19 43 55·62	51·55	+5·8729	+5·8152	+0·195	−66 46 49·1	51·7	+8·789	+9·264	−1·13
α Pavonis	20 5 41·37	51·55	4·8622	4·8258	+0·002	57 30 26	...	...	...	...
α Indi	20 19 51·79	51·59	4·2932	4·2687	+0·005	48 8 21·3	51·7	11·499	11·815	+0·11
β Pavonis	20 22 4·54	51·59	5·6434	5·5712	−0·006	67 4 7·3	52·0	11·654	12·067	0·00
β Indi	20 35 3·43	51·59	4·8316	4·7858	−0·001	59 22 19·6	51·8	12·563	12·899	+0·02
γ Pavonis	21 5 24·49	51·55	5·1905	5·1134	+0·010	66 28 17·4	52·2	14·519	14·835	+0·78
ν Octantis	21 12 31	...	...	...	...	78 28 1·1	51·8	14·942	15·375	−0·26
γ Gruis	21 38 42·41	51·55	3·6857	3·6659	+0·005	38 31 31·7	51·8	16·371	16·558	−0·02
α Gruis	21 52 20·60	51·59	3·8597	3·8303	+0·010	48 9 29·1	51·8	17·032	17·210	−0·13
α Toucani	22 1 7·13	51·59	4·2917	4·2354	−0·011	61 29 35·2	52·0	17·426	17·610	+0·01
β Octantis	22 18 34·92	51·75	7·5251	7·0361	−0·056	82 40 24·5	52·3	18·132	18·404	−0·03
β Gruis	22 27 36·53	51·59	3·6565	3·6282	+0·013	48 10 58·4	51·8	18·457	18·580	+0·01
τ Octantis	22 30 25	...	...	...	...	88 49 56·8	52·2	18·552	...	−0·02
α Piscis Australis	22 43 46	...	...	...	...	30 56 24·2	51 8	18·965	19·057	−0·17
γ Toucani	23 2 39·09	51·73	+3·6345	+3·5920	−0·007	59 36 0·8	52·1	19·440	19·514	+0·06
γ^1 Octantis	23 36 35	...	...	...	...	−83 24 27·2	52·5	+19·960	+19·990	0·00

F F

Blackheath:
May 10, 1888.

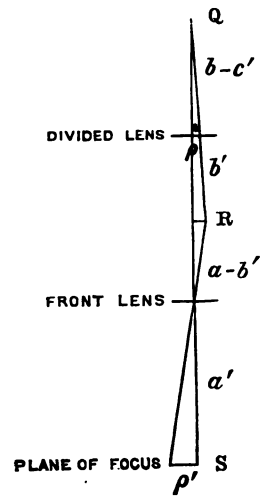
On the Condition that in a Double-Image Micrometer the value of a Revolution of the Micrometer Screw be independent of the Accommodation of the Eye. By Professor J. A. C. Oudemans.

Putting the focal lengths of the lenses of the micrometer (beginning from the object-glass), p, q, r, s; the intervals between the lenses (in the same order), a, b, c; then the proportions pointed out by Valz, adopted by Sir G. Airy, and by the constructors, Messrs. Troughton and Simms, are (*Monthly Notices*, vol. x. p. 161):

Focal length of front lens	$= p =$ arbitrary,*	
,, divided lens	$= q = -1$,	
,, field-glass	$= r = +1$,	
,, eye-glass	$= s = +1$,	
Interval between front and divided lens		$a = p$,
,, divided lens and field-glass		$b = 1$,
,, field-glass and eye-glass		$c = 3$.

Supposing the eye to be hypermetropic, so that it accommodates for rays converging to a point lying behind the eye-glass at a distance D, then, if we follow the rays of light from the eye to the focus of the micrometer, these rays, after passing each lens, will intersect the axis successively in four points, P, Q, R, S; if we put the distances of these points beyond the lastly passed lens, $= D'$, c', b', and a', these values all depend on D.

Let ρ be the distance between two successive turns of the micrometer screw, and ρ' the corresponding quantity in the measured object, we have



$$\frac{\rho'}{\rho} = \frac{a'}{a-b'}\left(1 + \frac{b'}{b-c'}\right)$$

or, putting $b - c' = e$,

$$\frac{\rho'}{\rho} = \frac{a'}{a-b'}\left(1 + \frac{b'}{e}\right);$$

but

$$b' = \frac{eq}{e-q},$$

thus

$$1 + \frac{b'}{e} = \frac{e}{e-q} = \frac{1}{1-\frac{q}{e}},$$

$$a' = \frac{(a-b')p}{a-b'-p} \qquad \frac{a'}{a-b'} = \frac{p}{a-b'-p}$$

$$\frac{\rho'}{\rho} = \frac{p}{a-\frac{eq}{e-q}-p} \cdot \frac{1}{1-\frac{q}{e}} = \frac{p}{(a-p)\left(1-\frac{q}{e}\right)-q}.$$

* In the micrometer, constructed by Messrs. Troughton and Simms for the Leyden Observatory, in 1855, there are four front lenses, giving four magnifying powers, and having a focal length of 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{3}$. The inch seems to have been taken as unity.

From this expression it follows that, in order that $\frac{\rho'}{\rho}$ be independent of e, and consequently of D, we ought to have $a=p$, a condition already fulfilled in the micrometer, with the intention of obtaining an equal division of light upon the two segments of the divided lens.

Taking $D=\infty$, i.e. supposing the eye accommodated for parallel rays, we have, in the construction adopted by Sir George Airy,

$$D'=s=1,$$
$$c-D'=2,$$
$$c'=2,$$
$$e=b-c'=-1,$$
$$\frac{q}{e}=1.$$

Now in the denominator of the expression found for $\frac{\rho'}{\rho}$, the multiplier of $a-p$ is $1-\frac{q}{e}$, and, consequently, if the equation $\frac{q}{e}=1$ be really satisfied, this multiplier is $=0$.

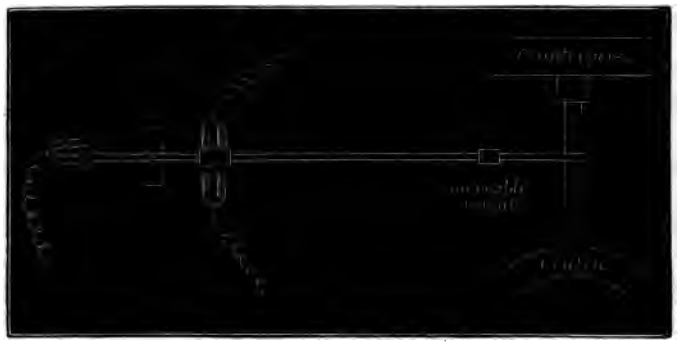
Generally a will not be *exactly* $=p$, and q will not be *exactly* $=e$, but the product of the two factors, $a-p$ and $1-\frac{q}{e}$, will always be very small in comparison with q, so that we may safely conclude that: *in a double-image micrometer, constructed according to the proportions originally pointed out by Valz, the value of one revolution of the micrometer screw is practically independent of the accommodation of the observer's eye.*

In the papers, published by Sir George about this micrometer, I have not found that this point was attended to. Of course, if the images are not very distinct, it is always allowed to thrust in or draw out the eye-tube, containing the field and eye glasses together, but there might remain a doubt whether, if a normal eye has adjusted the micrometer to the focus of the telescope, a hypermetropic or a myope would be justified in changing the distance between the object-glass of the telescope and the whole micrometer. By the above consideration this question is answered in the affirmative.

Utrecht:
1888, *May* 9.

Note on a Simple Method of applying Electrical Control to the Driving Clock of an Equatorial. By A. C. Ranyard, M.A.

As considerable attention is at present being paid to the methods of controlling driving clocks of equatorial telescopes by the motion of a seconds pendulum, I think that a notice of a simple addition which I am having made to my driving clock may be of interest. I am getting rid of my old driving wheel, and propose to substitute a driving sector of 3-foot radius in its place. This gears into an endless screw driven, as in Sir Howard Grubb's clock, by an axis on which is an insulated wheel with rubbers nearly similar to the contrivance described by Lord Crawford and Dr. Gill in the *Monthly Notices* for



November 1873. Instead of the epicycloidal accelerating and retarding wheels used by Sir H. Grubb, I propose to make use of the instantaneous current to act upon magnets which move a small weight attached to the end of a lever backwards or forwards from one side to the other of the fulcrum of the crutch which rubs upon the governor disc. When the little weight attached to the lever is on one side of the fulcrum it decreases the pressure of the crutch, and accelerates the motion of the governor, and when drawn to the other side it increases the pressure and retards the motion of the clock. When the clock is going correctly a magnet draws the lever to the central position over the fulcrum. My governor is similar to that figured by Mr. Common in the *Memoirs*, in describing the mounting of his great 37-inch reflector.

If it is preferred, the height of the fulcrum with respect to the rubbing disc of the governor can be altered by moving a lever attached to an adjusting screw supporting the fulcrum. But the weighted lever above described gives an additional means of adjustment, as a small nut running on a screw, and acting as a counterpoise weight, may be moved upon the lever, or the position of the horseshoe magnets may be moved within certain limits, either towards or away from one another, or up to or away from the centre of motion of the lever.

Observations of Sappho, made at the Cambridge Observatory by Mr. A. Graham with the Northumberland Equatorial and Square Bar-Micrometer.

(*Communicated by Professor J. C. Adams.*)

	Greenwich Mean Time.	Apparent R.A.	Apparent Decl.	Reduction to Geoc. Place in R.A.	Reduction to Geoc. Place in Decl.	Compared Star.	No. of Comps.	Correction of Ephemeris in R.A.	Correction of Ephemeris in Decl.
		h m s	° ′ ″	s	″			s	″
1888, April	14·39868	13 18 25·38	−12 8 0·05	−0·12	+4·66	*a*	10	+6·69	−34·34
	·39868	13 18 25·55	−12 7 57·53	−0·12	+4·66	*b*	10	+6·86	−31·82
	16·40366	13 16 34·05	−11 50 42·34	−0·11	+4·68	*c*	1	+6·52	−31·55
	·40366	13 16 34·57	−11 50 43·06	−0·11	+4·68	*d*	1	+7·03	−32·27
	18·39188	13 14 45·35	−11 33 29·92	−0·11	+4·65	*e*	10	+6·82	−31·98
	30·46232	13 4 35·66	− 9 50 50·03	+0·04	+4·66	*f*	5	+6·64	−35·49
	·46536	*g* −0 54·84	*g* +4 23·16	+0·04	+4·66	*g*	4		

Mean Places of Compared Stars for 1888·0, *with Reductions to Apparent Place.*

	R.A. 1888·0.	Decl. 1888·0.	Reduction to Apparent Place in R.A.	in Decl.	Authorities.
	h m s	° ′ ″	s	″	
a	13 16 13·16	−11 59 31·23	+1·31	−5·86	B. (W.) 13ʰ, 230.
b	13 20 48·23	−12 7 26·43	+1·31	−5·70	Greenwich Catalogue for 1872, 1230.
c	13 13 42·57	−11 53 37·34	+1·31	−6·04	B. (W.) 13ʰ, 193.
d	13 14 6·57	−11 52 45·88	+1·31	−6·04	B. (W.) 13ʰ, 202.
e	13 12 56·35	−11 25 30·00	+1·31	−6·14	Place given in Mr. Bryant's Ephemeris.
f	13 8 52·92	− 9 46 31·73	+1·31	−6·40	Argentine Catalogue 18023.
g	13 5 28·96	− 9 55 5·45	+1·30	−6·54	By 4 comparisons with (*f*) April 30.

On April 26, probably by some mistake in giving the time, a small star was observed instead of the planet. The places of several stars, deduced from 11 comparisons, with B. (W.) 13ʰ·34 on that night may be useful to other observers.

	R.A. 1888·0.	Decl. 1888·0.	Mag.	Reduction to Apparent Place in R.A.	in Decl.
	h m s	° ′ ″		s	s
Assumed place of B. (W.) 13ʰ·34	13 5 25·63	−10 30 29·78	9	+1·31	−6·57
	13 6 33·79	−10 25 6·44	9	+1·31	−6·51
	13 6 50·98	−10 25 28·13	12	+1·31	−6·51
	13 8 52·82	−10 27 9·38	9·6	+1·31	−6·43

Note.—The places of the above stars of comparison, as well as those of the stars in Mr. Bryant's Ephemeris, have been observed with the Cambridge Transit Circle, but the observations have not yet been reduced.

Cambridge Observatory: 1888, *May* 3.

Occultations of Stars observed during the Lunar Eclipse of 1888, *January* 28. By E. Nevill, Government Astronomer.

By mischance we did not receive until two days after the eclipse the list of phenomena calculated for this observatory by Dr. Döllen, and so were dependent for our information on a copy of the list of stars occulted at the Cape, which was forwarded to us by Dr. Gill a few days before the eclipse.

The observations were made by myself with the 8-inch Grubb Refractor, power 125, the times being noted and recorded by my assistant, Mr. Grant.

The Moon's limb, though eclipsed, was too bright to enable stars of the 10th or 11th magnitude to be observed with any certainty.

Star. No. on Döllen's List.	Phenomena.	Observed Greenwich Mean Time. h m s	Star. No. on Döllen's List.	Phenomena.	Observed Greenwich Mean Time. h m s
86	Reapp.	10 40 42·0	143	Disapp.	11 12 5·2
129	Disapp.	44 8·1	147	Disapp.	18 27·7
127	Disapp.	48 49·6	95	Reapp.	20 38·8
122	Disapp.	50 23·8	159	Disapp.	33 25·4
76	Reapp.	11 1 51·3	122	Reapp.	59 42·6
88	Reapp.	3 3·5	169	Disapp.	12 3 10·9
68	Reapp.	4 17·8	179	Disapp.	5 30·2
*	Disapp.	9 29·7	127	Reapp.	10 1·9
140	Disapp.	9 53·2			

In all 17, or 10 disappearances and 7 reappearances.

Natal Observatory:
1888, *April* 4.

Observation of the Occultation of Venus by the Moon, 1888, March 9. By John Tebbutt.

Having on the evening of the 10th instant completed a set of filar-micrometer measures of the position of the comet now visible, I turned the 8-inch telescope on the Moon to observe the occultation of *Venus*, then shining brilliantly, immediately beneath the lunar crescent. The magnifying power employed for the observation was 130 diameters, and the sky was fortunately beautifully clear. As there was considerable undulation along the Moon's limb in consequence of her low altitude I could not observe the disappearance with satisfaction. The planet's terminator was noted to be in contact with the Moon's limb at $17^h\ 34^m\ 21^s{\cdot}3$ local mean time, but to my surprise the illuminated portion of the planet's disc, instead of disappearing, advanced gradually on the lunar disc till it was fully half projected on it, then suddenly at $17^h\ 34^m\ 43^s{\cdot}8$ the projected portion of the disc disappeared, and the planet assumed a semicircular form with the Moon's limb as the diameter. The total disappearance of the planet was noted as accurately as possible at $17^h\ 34^m\ 57^s{\cdot}7$. There was a remarkable contrast between the brilliancy of the planet and that of the Moon's limb, the former being by far superior. The reappearance was observed with the same telescope and magnifying power. The disappearance itself was a most interesting phenomenon, but the reappearance was still more interesting and indeed striking. The planet's terminator shot out from the grey sky in the field of the telescope as a brilliant streak at $18^h\ 56^m\ 18^s{\cdot}6$. The definition was good, and the objects more steady than at the disappearance. The gradual progress of the Moon's dark limb over the planet's illuminated disc was watched with interest, and at $18^h\ 56^m\ 44^s{\cdot}8$, but probably a second late, the last contact of limbs occurred. I believe this is the first occultation of *Venus*, and the fourth of a bright planet that I have witnessed during an experience of more than thirty years.

Windsor, N. S. Wales:
1888, *March* 14.

Observations of Comet 1888 *a* (*Sawerthal*) *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

Comet 1888 *a* (*Sawerthal*).

Greenwich Mean Solar Time.		Observer.	♂−✱ R.A.	Corr. for Par. and Refraction in R.A.	♂−✱ N.P.D.	Corr. for Par. and Refraction in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1888.	h m s		m s	s	′ ″	″		h m s	° ′ ″	
April 18	15 44 15	HT.	+4 5·80	−0·30	− 3 8·9	−4·8	4	22 52 40·40	70 56 50·1	*a*
18	15 44 15		+3 9·05	−0·30	− 5 30·7	−4·9	4	22 52 40·35	70 56 42·0	*b*
18	15 51 43		+4 8·75	−0·30	+ 3 28·5	−4·1	2	22 52 41·55	70 56 32·3	*c*
26	15 16 4	HT.	+1 4·90	−0·30	− 5 6·5	−4·4	6	23 13 34·00	65 39 22·8	*d*
26	15 16 4		−2 25·43	−0·30	− 0 45·4	−4·1	6	23 13 34·27	65 39 24·1	*e*
26	15 16 31		+3 28·85	−0·30	− 0 48·0	−4·1	2	23 13 33·75	65 39 31·0	*f*
26	15 16 31		+3 7·90	−0·30	−11 2·4	−4·8	2	23 13 33·50	65 39 26·1	*g*
29	14 16 33	L.	+0 14·21	−0·30	+ 0 16·2	−4·2	17	...	...	*h*
29	14 30 56		+0 2·92	−0·37	− 8 13·2	−5·1	6	23 20 52·55	63 55 7·7	*i*
29	14 49 16		+2 16·75	−0·30	− 2 11·4	−4·3	4	23 20 57·65	63 54 33·9	*j*
May 3	15 13 20	HT.	−0 9·13	−0·30	− 0 0·5	−3·6	6	23 30 33·57	61 43 21·1	*k*
4	15 5 55	HT.	+1 1·98	−0·30	− 4 1·8	−3·7	4	...	...	*l*
4	15 17 10		−5 26 65	−0·30	− 3 28·5	−3·7	4	23 32 54·00	61 12 11·1	*m*
5	13 53 28	HT.	+6 58·00	−0·30	− 1 5·0	−4·1	3	23 35 3·20	60 43 33·7	*n*
5	13 59 53		+4 0·00	−0·30	+ 5 45·1	−3·3	2	...	...	*o*
7	13 28 15	H.	−0 6·30	−0·30	+ 0 4·8	−4·1	1	...	...	*p*
10	13 54 2	T.	−1 3·50	−0·30	+ 3 32·6	−3·4	6	23 46 25·80	58 16 33·9	*q*

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1888·0.	N.P.D., 1888·0.	Authority
		h m s	° ′ ″	
a	W.B. (2) XXII. 1087	22 48 35·64	70 59 53·7	Lamont.
b	W.B. (2) XXII. 1109	22 49 32·42	71 2 7·6	Lamont.
c	Arg. Zone + 18°, No. 5064	22 48 33·90	70 52 57·9	Lamont.
d	W.B. (2) XXIII. 219	23 12 30·00	65 44 22·8	Weisse's Bessel (2).
e	W.B. (2) XXIII. 291–2	23 16 0·72	65 40 2·6	Weisse's Bessel (2).
f	Arg. Zone + 24°, No. 4738	23 10 5·90	65 40 12·1	Rümker.
g	W.B. (2) XXIII. 169–70	23 10 26·61	65 50 22·4	Weisse's Bessel (2).
h	Arg. Zone + 25°, No. 4935	23 20 42	63 54	Bonn Observations, Vol. IV.
i	Arg. Zone + 25°, No. 4936	23 20 50·65	64 3 14·9	Bonn Observations, Vol. VI.
j	W.B. (2) XXIII. 350	23 18 41·87	63 56 38·5	Weisse's Bessel (2).
k	W.B. (2) XXIII. 621–2	23 30 43·60	61 43 13·7	Weisse's Bessel (2).
l	Arg. Zone + 28°, No. 4608	23 31 48	61 19	Bonn Observations, Vol. IV.
m	78 Pegasi	23 38 21·46	61 15 31·9	Greenwich 9-Year Catalogue.
n	W.B. (2) XXIII. 566	23 28 6·06	60 44 31·3	Weisse's Bessel (2).
o	Arg. Zone + 29°, No. 4969	23 31 3	60 38	Bonn Observations, Vol. IV.
p	Arg. Zone + 30°, No. 5015	23 39 36	59 33	Bonn Observations, Vol. IV.
q	Lalande 46809	23 47 30·12	58 12 52·9	Lalande.

Notes.

April 26.—Nucleus only visible; no trace of a tail could be seen in the strong moonlight and approaching daylight.

May 3.—The comet became very faint towards the end of the series of observations; tail visible at first.

4.—Comet very faint at last comparison.

5.—Comet not at all easy to observe; tail traceable for 20′.

7.—This observation was made during a break in the cloud; comet had a distinct nucleus, and a very perceptible tail.

10.—Comet faint, with long, straight, but very faint tail.

The observations are corrected for parallax and refraction. The initials HT., T., L., H. are those of Mr. Turner, Mr. Thackeray, Mr. Lewis, and Mr. Hollis respectively.

Observation of Comet 1888 *a* (*Sawerthal*) *with the Altazimuth.*

From an observation of Comet *a*, made on the morning of May 2, with the altazimuth, with the graduated face of the vertical circle left, the following position, corrected for parallax and refraction, was obtained:—

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D.
1888. h m s		h m s	° ′ ″
May 1 13 34 35	T.	23 25 40·57	62 50 35·0

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1888·0.	N.P.D., 1888·0.	Authority
		h m s	° ′ ″	
a	W.B. (2) XXII. 1087	22 48 35·64	70 59 53·7	Lamont.
b	W.B. (2) XXII. 1109	22 49 32·42	71 2 7·6	Lamont.
c	Arg. Zone + 18°, No. 5064	22 48 33·90	70 52 57·9	Lamont.
d	W.B. (2) XXIII. 219	23 12 30·00	65 44 22·8	Weisse's Bessel (2).
e	W.B. (2) XXIII. 291–2	23 16 0·72	65 40 2·6	Weisse's Bessel (2).
f	Arg. Zone + 24°, No. 4738	23 10 5·90	65 40 12·1	Rümker.
g	W.B. (2) XXIII. 169–70	23 10 26·61	65 50 22·4	Weisse's Bessel (2).
h	Arg. Zone + 25°, No. 4935	23 20 42	63 54	Bonn Observations, Vol. IV.
i	Arg. Zone + 25°, No. 4936	23 20 50·65	64 3 14·9	Bonn Observations, Vol. VI.
j	W.B. (2) XXIII. 350	23 18 41·87	63 56 38·5	Weisse's Bessel (2).
k	W.B. (2) XXIII. 621–2	23 30 43·60	61 43 13·7	Weisse's Bessel (2).
l	Arg. Zone + 28°, No. 4608	23 31 48	61 19	Bonn Observations, Vol. IV.
m	78 Pegasi	23 38 21·46	61 15 31·9	Greenwich 9-Year Catalogue.
n	W.B. (2) XXIII. 566	23 28 6·06	60 44 31·3	Weisse's Bessel (2).
o	Arg. Zone + 29°, No. 4969	23 31 3	60 38	Bonn Observations, Vol. IV.
p	Arg. Zone + 30°, No. 5015	23 39 36	59 33	Bonn Observations, Vol. IV.
q	Lalande 46809	23 47 30·12	58 12 52·9	Lalande.

Notes.

April 26.—Nucleus only visible; no trace of a tail could be seen in the strong moonlight and approaching daylight.

May 3.—The comet became very faint towards the end of the series of observations; tail visible at first.

4.—Comet very faint at last comparison.

5.—Comet not at all easy to observe; tail traceable for 20′.

7.—This observation was made during a break in the cloud; comet had a distinct nucleus, and a very perceptible tail.

10.—Comet faint, with long, straight, but very faint tail.

The observations are corrected for parallax and refraction. The initials HT., T., L., H. are those of Mr. Turner, Mr. Thackeray, Mr. Lewis, and Mr. Hollis respectively.

Observation of Comet 1888 *a* (*Sawerthal*) *with the Altazimuth.*

From an observation of Comet *a*, made on the morning of May 2, with the altazimuth, with the graduated face of the vertical circle left, the following position, corrected for parallax and refraction, was obtained:—

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D.
1888. h m s		h m s	° ′ ″
May 1 13 34 35	T.	23 25 40·57	62 50 35·0

Observations of the Spectrum of Comet 1888 *a* (*Sawerthal*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The comet was looked for on several mornings, but owing to the prevalence of cloud in the east before sunrise was only seen on three occasions.

On April 10 a momentary glimpse was caught of the comet between heavy clouds and through light cloud. The spectrum was of the last degree of faintness, and was supposed at the time to consist simply of the green band of the usual cometary spectrum, without any trace of a continuous spectrum. The observations on April 19 and May 3 render it probable that what was seen was simply the brightest part of the continuous spectrum.

On April 19 the comet was seen again, but still with great difficulty, and always through cloud; the daylight, too, had begun to be strong before the comet could be seen at all.

The spectrum of the comet was mainly continuous. The spectrum, as seen, was probably from the nucleus and immediate neighbourhood only, but, so far as it could be traced, was almost entirely of a continuous character. Two feeble bands were just glimpsed, nearly, if not quite, coincident with the green and yellow bands of the spectrum of the Bunsen flame. The blue band could not be quite satisfactorily made out in the spectrum of the comet, but there seemed some feeble brightening in its neighbourhood, that might be taken as an indication of its presence. Finally, a very fair direct comparison was obtained in the case of the green band, which left no doubt of its coincidence with the corresponding band of the spectrum of the Bunsen flame.

On May 3 the comet was seen again, this time in a clear sky; and its spectrum was found to be practically wholly continuous. The band spectrum was evidently very much feebler in proportion to the continuous spectrum than on April 19, for no trace of the bands in the yellow and blue could be detected, and the band in the green, though searched for very carefully with every variety of slit-width, could only be very faintly suspected, as a feeble local brightening of the continuous spectrum, from the envelope immediately surrounding the nucleus of the comet. The continuous spectrum ended rather abruptly at, or very near, D. The tail of the comet was traced in the finder as a straight beam of light for a considerable distance from the nucleus, and its spectrum could just be seen in the spectroscope, and apparently was, like that of the head, of a continuous character, differing only from it in being far more faint.

No measures could be obtained on either of the three dates of observation. The observations were made throughout by Mr. Maunder, using the single prism spectroscope mounted upon the 12·8-inch refractor.

Observations of Comet a 1888 (*Sawerthal*), *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following observations of Comet Sawerthal were made with the Barclay Equatorial, using the ring-micrometer, with power 100.

1888.	Greenwich Mean Time.	Observer.	Comet−Star Δ R.A. (Corrected for Refraction only.)	Comet−Star Δ N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Log. $p\Delta$	Apparent N.P.D. of Comet.	Log. $p\Delta$	Comp. Star.
	h m s		m s	′ ″		h m s		°		
April 6	15 32 0	W.	+0 24·37	−4 11·0	2	22 18 23·73	9·4784	81 2 1·0	0·7430	1
6	15 34 14	W.	+0 51·73	−4 27·3	4	22 18 23·70	9·4784	81 2 1·7	0·7430	2
May 1	13 18 3	W.	+0 17·47	−0 15·7	12	23 25 38·69	9·3842	62 49 54·0	0·6579	3
1	14 17 58	W.	−4 34·81	+3 9·5	4	23 25 45·09	9·4155	62 48 36·7	0·6174	4
2	13 30 45	R.	+1 54·31	+4 7·4	2	23 28 3·58	9·3930	62 17 9·0	0·6428	5
3	13 59 36	F. B.	−1 25·18	+7 16·9	9	23 30 27·46	9·4078	61 44 58·8	0·6193	6
3	14 47 9	F. B.	−0 11·19	+0 33·5	16	23 30 31·73	9·4167	61 43 58·2	0·5820	7
3	14 47 9	F. B.	−1 20·61	+6 11·5	16	23 30 32·03	9·4167	61 43 53·4	0·5820	6
4	13 35 7	W.	−5 36·23	−1 11·5	10	23 32 44·60	9·3952	61 14 31·2	0·6303	8

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent Place.	Mean N.P.D. 1888·0.	Reduction to Apparent Place.	Authority.
	h m s	s	° ′ ″	″	
1	22 18 0·31	−0·95	81 6 4	+ 8·0	½ (Lamont 6282 + Arg. Zone 8°, No. 4861).
2	22 17 32·92	−0·95	81 6 21·0	+ 8·0	½ (Lal. 43671–2 + Lamont 6279 + Armagh II. 3008). Adopted proper motion of +0ˢ·020 in R.A.
3	23 25 21·83	−0·61	62 49 58·5	+ 11·2	Mean of two measured differences from No. 4 comparison star made with the ring-micrometer.
4	23 30 20·53	−0·63	62 45 16·0	+ 11·2	Armagh II. 3212.
5	23 26 9·88	−0·61	62 12 50·4	+ 11·2	Armagh II. 3196.
6	23 31 53·26	−0 62	61 37 30·6	+ 11·3	Mean of two measured differences from star γ made with the ring-micrometer.
γ	23 24 16·43	−0·61	61 43 8·0	+ 11·3	½ (Lalande 46006 + W.B. (2) XXIII.–485).
7	23 30 43·54	−0·62	61 43 13·4	+ 11·3	W.B. (2) XXIII. 621–2 (mean).
8	23 38 21·45	−0·62	61 15 31·4	+ 11·4	½ {Radcliffe (1860) 2349 + Greenwich (1872) 2223}.

Observers' Remarks.

1888, April 6.—The nucleus dead white, well defined, and elongated, thus

At times I thought the nucleus double. Estimated as brighter than the star *Lal.* 43671–2 by a magnitude. The tail was distinctly visible to the naked eye.

April 15.—Nucleus as bright as an 8 mag. star. The tail well visible to the naked eye, and is nearly 5° long. Estimated as equal to the distance between γ and β *Aquilæ*. (Observer R.)

May 1.—Comet about $\frac{1}{3}$ as bright as on April 6. Invisible to naked eye.

2.—Cloudy. Wind gusty. Comet faint.

3.—Central part of the elongated nucleus observed. The comparison star No. 7 is double, mean observed.

4.—The images to-night diffused at times. Nucleus still elongated.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

Radcliffe Observatory, Oxford:
1888, *May* 12.

Observations of Comet a 1888 (*Sawerthal*), *in February and March, made at Launceston, Tasmania. Lat. S.* 41° 26′ 1″. *Long. E.* 9h 48m 31s. By A. B. Biggs.

(*Communicated by H. H. Turner.*)

February 25.—L.M.T. 4h 52m 15s A.M.

Comet from Star (?) 8221 *Lacaille.* (*Comet S.P.*)

Greenwich M.T.	Diff. R.A.	Diff. N.P.D.	No. of Meas.	Remarks.
h m s	m s	′ ″		
Feb. 24 7 3 42	−0 8·08	+1 23·2	3	Star uncertain.* Only one measure for position, advancing daylight and haze preventing verification. Nucleus bright, well-defined, and surrounded with considerable coma. Brightness about = comparison star.

March 8.—L.M.T. 4h 37m 7s A.M.

Comet from Star 8546 *Lacaille.* (*Comet N.F.*)

	h m s	m s	′ ″		
Mar. 7	6 48 36	+1 22·12	−8 49·8	4	Nucleus sharply defined. Less coma about head. Tail more tapering towards the head. Brightness about = comparison star.

March 11.—L.M.T. 5h 21m 55s A.M.

Comet from Star (?) 8566 *Lacaille.* (*Comet N.F.*)

	h m s	m s	′ ″		
Mar. 10	7 19 14	+(9)* 11	missed		* Minutes uncertain—probably 9 in both cases.
	7 33 24	(8)* 14·5	−6 03·7	1	

March 16.—L.M.T. 5h 18m 46s A.M.

Comet from Star 30 *Capri.* (*Comet S.P.*)

	h m s	m s	′ ″		
Mar. 15	1 30 15	−3 40·25	+7 47	1	Brightness about = comparison star.

March 18.—L.M.T. 5h 4m 24s A.M.

Comet from Star 29 *Capri.* (*Comet S.F.*)

	h m s	m s	′ ″		
Mar. 17	7 15 53	+5 02·5	+2 39·03	4	All good measures. Brightness—Comet ∠ star.

* Much the brightest star in a wide field.

General Remarks.—On other dates circle readings only have been taken for position, but as the telescope has worked somewhat out of adjustment, these are of little value. This has rendered some of the star identifications uncertain.

No reductions have been made in the above measures for refraction, &c. This would be only for the small difference in declination, the telescope being fixed in R.A. for each observation.

In all cases the *brightest* available star has been used.

Telescope, 8½-inch reflector.

Further observations prevented by a succession of cloudy mornings.

Launceston:
1888, *March* 24.

Sextant Observations of Comet a 1888, *extracted from the Meteorological Log, No.* 7120, *kept on board the barque 'Atlantic.'* By Captain R. Belding.

(*Communicated by Captain H. Toynbee.*)

1888, *March* 10, 4 A.M, Lat. 22° 17′ S., Long. 26° 45′ W.—Angular distance from the comet's nucleus

to α Centauri 68° 43′. G.M.T. $6^h\ 56^m\ 24^s$;
to Antares 58° 51′. G.M.T. $7^h\ 2^m\ 24^s$.

March 11, 4 A.M., Lat. 21° 40′ S., Long. 27° 9′ W.—Angular distance from the comet's nucleus

to α Centauri 70° 25′. G.M.T. $6^h\ 8^m\ 15^s$;
to Antares 59° 56′. G.M.T. $6^h\ 3^m\ 25^s$;
to Altair 37° 39′.

The comet appeared to be brighter this morning, and bearing about E. by S. ½ S. (true.)

March 12, 4 A.M., Lat. 20° 57′ S., Long. 27° 5′ W.—Comet has a larger and brighter appearance. Angular distance from comet's nucleus

to Antares 61° 11′. G.M.T. $6^h\ 42^m\ 30^s$;
to α Centauri 72° 12′. G.M.T. $6^h\ 48^m\ 10^s$;
to Altair 36° 42′. G.M.T. $6^h\ 55^m\ 30^s$.

March 14, 4 A.M., Lat. 19° 55′ S., Long. 27° 5′ W.—Comet seen again. The tail appears to be curving more to the S.W. Angular distance from comet's nucleus

to Antares 63° 27′. G.M.T. $6^h\ 39^m\ 40^s$;
to α Centauri 75° 36′. G.M.T. $6^h\ 44^m\ 25^s$;
to Altair 35° 0′. G.M.T. $6^h\ 50^m\ 44^s$.

March 15, 4 A.M., Lat. 18° 31′ S., Long. 27° 28′ W.—Angular distance from comet's nucleus

to Antares 64° 51′. G.M.T. $6^h\ 22^m\ 43^s$;
to α Centauri 77° 14′. G.M.T. $6^h\ 29^m\ 44^s$;
to Altair 34° 20′. G.M.T. $6^h\ 39^m\ 53^s$.

March 17, 4.30 A.M., Lat. 14° 1′ S., Long. 28° 3′ W. (by interpolation)—Angular distance from comet's nucleus

to Antares 67° 26′. G.M.T. $6^h\ 43^m\ 3^s$;
to α Centauri 80° 35′. G.M.T. $6^h\ 50^m\ 58^s$;
to Altair 33° 3′. G.M.T. $6^h\ 57^m\ 35^s$.

The comet's nucleus appeared to be brighter, and also to vary in brightness. The tail looked lighter and thinner.

March 22, 4 A.M., Lat. 1° 59′ S., Long. 28° 49′ W. (by interpolation)—Comet seen again. Angular distance from the nucleus

to Antares 73° 50′. G.M.T. $6^h\ 18^m\ 44^s$;
to α Centauri 88° 35′. G.M.T. $6^h\ 25^m\ 31^s$;
to Altair 31° 27′. G.M.T. $6^h\ 32^m\ 56^s$.

March 24, 4 A.M., Lat. 0° 39′ N., Long. 29° 38′ W. (by interpolation)—Angular distance from comet's nucleus

to Antares 76° 26′. G.M.T. $6^h\ 59^m\ 10^s$;
to Altair 31° 27′. G.M.T. $7^h\ 3^m\ 51^s$.

Observations corrected for index error only.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. JUNE 8, 1888. No. 8

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

John Harvey Jones, Fairview Villa, Coburg Road, Montpelier, Bristol (proposed by W. F. Denning);

William Henry Maw, Civil Engineer, 18 Addison Road, Kensington, W. (proposed by Sir H. Grubb); and

Albert Taylor, Observatory, Hurstside, West Molesey, Surrey (proposed by J. Norman Lockyer).

Photographic Committee.

At a meeting of the above Committee, appointed by the Council of the Royal Astronomical Society, the following resolutions were passed unanimously:—

1. That this Committee is of opinion that it is undesirable to reopen any fundamental questions settled by the Astrophotographic Congress, and therefore considers that it is not desirable to extend the limits of magnitude for the stars of the photographic chart of the heavens beyond that already defined by that Congress.

2. That this Committee expresses its strong disapproval of the scheme for an International Bureau for measuring the stellar photographs, as proposed in the *Bulletin du Comité International Permanent.*

The Library.

In accordance with a resolution of the Council, the Library of the Society will in future be closed on the FIRST and THIRD Saturdays in each month at 2 P.M.

The Central Office for Astronomical Telegrams.
By Professor A. Krueger.

(*Extract from a letter to the President.*)

I have been often surprised that the Central Office for Astronomical Telegrams has only one subscriber in England, while in France we have 5, in Spain and Portugal 3, in Italy 5, in Germany 12, in Austria 4, in Switzerland 3, in Russia 12, in Scandinavia 4, and in Holland and Belgium 4.

Perhaps you would bring the matter before a meeting of the R.A.S. The yearly contribution for those who do not desire telegrams of discoveries of minor planets is at present 2*l.*, or including minor planets, 3*l.*

As the number of subscribers increases, the yearly subscription will be reduced, by reason of the necessary expenses of management being divided among a greater number.

New Arrangement of Electrical Control for Driving Clocks of Equatorials. By Sir Howard Grubb, F.R.S.

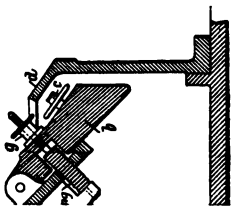
In a paper read before this Society last spring I mentioned that it appeared to me likely that the best system for obtaining accurate clock-driving, and that most suitable for photographic work, would be found to be a combination of Dr. Gill's as applied to Lord Crawford's 15-inch equatorial, and mine as applied to Mr. Roberts's equatorial.

I have since worked this out, and the driving apparatus I exhibit to-night (which is intended for the stellar photographic instrument of the Mexican, Chapultepec, Observatory) is the result.

There is nothing novel to remark on in the clock itself except the governor.

In Dr. Gill's control, as applied to the Earl of Crawford's telescope, and in my earliest form, the correction was applied to the governor by an increase or decrease of friction, and it was therefore desirable to keep down the *vis inertiæ* of the governor, but as, in this form, the correction is applied in a totally different manner, it is permissible to employ a very heavy, quick-moving governor, with a corresponding increase of *vis inertiæ*, and this has, as can easily be understood, great advantages in many ways, more particularly in the obtaining of great smoothness of motion.

In this particular governor, instead of balls I use a brass ring loaded with lead, and cut into eight segments; and in addition to gravity, springs are applied, one to each segment, tending to supplement the force of gravity; by which arrangement the speed of the governor is increased from 90 to 135 revolutions,



STANDARD

he *vis inertiæ* is represented by some 10,000 foot-pounds
inute.
s the great weight of this governor would cause a con-
able amount of friction in the toe bearings, a pair of
ned steel discs, between which a set of bicycle balls roll,
troduced at upper end of spindle. See fig. 1, Plate 2.
gain, to reduce the number of wheels, and consequent errors
en the governor and the screw spindle, the governor spindle
nished with a screw, *e*, on upper end, which gears directly
wheel, *f*, fig. 2, on counter spindle of screw shaft.
his is a suggestion of Dr. Gill's.
he system of control may be conveniently divided into two
ct parts: first, the *detector*; and, second, the *corrector*;
his second part, the *corrector*, is again divided into the
rator and the *retarder*.
he detector is seen at K, fig. 2, and also in perspective in
. It consists of three discs of brass, separated by discs of
te on which three metallic wipers rub, the brass discs being
t on edge that the central one presents a set of twenty
contact teeth, and each of the others twenty contact spaces
ated by spaces of no contact.
he three discs, which revolve together in twenty seconds, are
anged that no two contacts take place at the same time.
ny current sent through this wheel and contacts will be
into one or other of the three wipers, whichever is in
ct at the exact moment the current passes.
rom these three wipers the current is sent into one or other
e three electro-magnets of the relay (figs. 4 and 5), which
e placed at any distance.
the current passes at the moment the centre disc with its
sharp contact is under its wiper, it is directed into the
l electro-magnet of the relay (figs. 4 and 5), which tends
ep the lever central, and in contact with neither of the
um contacts at the other end.
the current passes at any other moment, it is directed into
r other of the side electro-magnets, and the lever of relay is
n to one side or another, and makes contact, which brings
lay the accelerator or retarder of the correcting apparatus.
ne correctors consist of two pairs of differential wheels, of
rdinary type of those used in my equatorials for slow
n in R.A.
he counter-shaft is discontinuous, being cut across between
pair of differential wheels. On the adjacent ends of this
tinuous shaft toothed wheels, *n m*, fig. 2, are attached,
ith a difference of one tooth in forty. Across both wheels
a pinion, *r* or *r'*, carried on a stud on a plate or disc, itself
move round the shaft.
the normal condition of working, the whole of the
gement revolves together, acting as a clutch, but if the
arrying the pinion be stopped the motion is transmitted

from the wheel *m* to *n through the pinion*, and a difference of rate + or − occurs according as the driver or the driven wheel has the greater number of teeth. The periphery of the disc is cut into fine teeth, and the armature of an electro-magnet suitably placed is provided with a comb, which engages in these fine teeth and stops the disc whenever that particular electro-magnet has the current directed into it by the relay above described.

The action of this apparatus is as follows: A pendulum beating seconds, shown diagrammatically at G, fig. 2, and more in detail in figs. 6 and 7, closes a circuit once every second, and allows a current from the battery H to flow through the wires 1 and 2 to the central contact ring of the detector. If the telescope is being driven properly this closing of the circuit by the pendulum will be synchronous with the passage of one of the central series of peripheral contact pieces under the contact spring connected to the wire 3, and the current will thus follow the circuit 1, 2, 3, 4, and 5, bringing into action the central electro-magnet of the relay. Referring to figs. 4 and 5, it will be seen that this relay has a vibrating lever, which, when acted upon by the armature of the central electro-magnet, is held in the central position, the effect of its being so held being that no current is transmitted by the relay, and the driving of the telescope is not interfered with. Let us suppose, however, that at the instant the pendulum closes its circuit the telescope is slightly ahead of its proper position. In this case, instead of one of the central series of contact pieces being under the contact spring when the circuit is closed, one of the right-hand series will be under *its* spring, and the circuit will follow the wires 1, 2, 8, 9, 5, bringing into operation the right-hand electro-magnet of the relay, and drawing the lever of the latter over to one side. The effect of this movement of the lever is to close a connection at 10, and cause a current from the battery I to traverse the circuit 13, 10, 11, 12, and bring into action the magnets actuating the clamp which will hold the disc *q* of the retarder, thus retarding the motion of the telescope. On the other hand, if the telescope falls behind its proper rate, the current transmitted by the pendulum will traverse the circuit 1, 2, 6, 7, 5, the lever of the relay will be drawn over to close the circuit at 14, and the current from the relay battery I will traverse the circuit 13, 14, 15, 16, and bring into action the clamp operating the accelerating disc *l*.

The shaft A makes one revolution in 20 seconds, so that during each revolution twenty correcting currents are transmitted by the controlling pendulum. The proportions of the accelerator and retarder are also such that the alteration made in the driving of the telescope equals $\frac{1}{40}$th of the time during which the accelerator or retarder is put into operation. Thus, if the driving of the telescope from any cause becomes $\frac{1}{20}$th of a second in arrear, the controlling apparatus will correct the error

by bringing the accelerator into action for a period of 2 seconds, and so on.

The seconds pendulum by which the control is exerted is shown in detail by figs. 6 and 7. It may be a mercurial or any other type of compensated pendulum, and its bob *a* carries a fine point *b* which at each oscillation closes an electric circuit by passing through a globule of mercury, and so transmits the current to the detector gear already described. The mode of driving the pendulum is as follows: The upper part of the pendulum rod carries a light arm *c*, which as the pendulum oscillates from right to left picks up the weight *f*, shown in fig. 7 as resting on the supporting lever *d*. If the latter remained in the position there shown the arm *c* would simply redeposit the weight at the same level during the reverse oscillation of the pendulum and the latter would receive no impulse. But just before the weight can be thus redeposited the closing of the electric circuit by the pendulum brings into action the electro-magnet *e*, which, attracting the armature, draws down the lever *d*. On the current ceasing and the armature being released, the lever *d* is restored by its counterweight to the position shown in fig. 7, of course relieving the arm *c* of the load *f*. The effect of this is that the weight *f* remains resting on the arm *c* for a longer arc while descending than while ascending, and hence the pendulum receives the necessary impulse.

Slow Motion in R.A.—Besides the ordinary slow motion in R.A. it is purposed to provide a very delicate slow motion, specially suited for correcting, for refraction, &c.

This is accomplished by another set of correctors similar to those above described, and acted on by another pair of electro-magnets (shown at the other end of the counter-shaft in fig. 2).

These electro-magnets are excited from a commutator held in the hand of the observer while watching a star in the guiding telescope.

If he finds a correction necessary, a pressure on one key of the commutator produces a temporary acceleration of $\frac{1}{40}$th part, and a pressure on the other a retardation to the same amount.

This arrangement acts absolutely without any backlash or jerk to instrument.

Note.—It is necessary to employ a second set of correctors for this, for if the same set as that actuated by the automatic control were used, the detector would treat the hand correction as an error and proceed to undo it again.

It is well to mention, in case it may appear that the arrangement shown in fig. 2 is complicated, that in the normal state of things the counter-shaft, with all its correctors, detectors, &c., revolves as one solid piece, and it is only when any correction has to be made that any of this work comes into action.

Slow Motion in Declination.—Every telescope-worker knows how impossible it is to get a declination slow motion absolutely free from "loss," unless by the so-called German form, in which

a screw acts against a long pliable spring, to which there are serious objections. In the arrangement shown in figs. 8 and 9 the advantage of having all backlash taken up by a spring is retained, while a very stiff spring can be employed. In figs. 8 and 9, *a* is

Fig. 8.

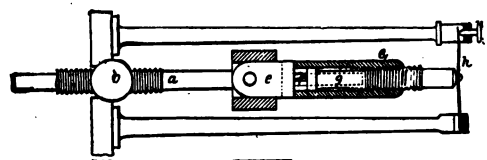
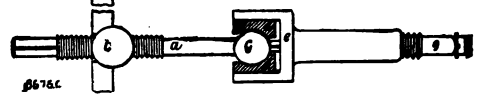


Fig. 9.



the screw by which the adjustment is made, this screw working through a nut *b*, and having a spherical end *c* bearing in the crosshead *d*. Thus, as the screw is turned the distance between the nut *b* and crosshead *d* is varied. At *h* is a short stiff spring, which by means of the screw *g* and sleeve *e* exerts a pressure on the crosshead *d*. At *f* is a square prolongation of the screw *a*, which enters a correspondingly squared hole in the screw *g* so that the latter turns with *a*. But whereas the screw *a* has a right-hand thread, that of the screw *g* is left-handed, so that every increase of distance between the nut *b* and crosshead *d* is accompanied by an equal decrease in the length of the combination *g e*, and thus the pressure exerted by the spring remains constant, whatever may be the position of the crosshead *d*.

Description of a New Observatory for a 3-foot Reflector.

By Edward Crossley.

On the removal of Mr. Common's 3-foot reflector from Ealing the ingenious wooden house, or observatory, designed by Mr. Common was also re-erected at Halifax. The situation at Halifax being much more exposed than that at Ealing, it was soon found very desirable to put up a dome so as more effectively to protect both the instrument and the observer. The present dome was completed in 1887. It is constructed in a similar manner to the excellent dome by Messrs. Cooke of York, at the Greenwich Observatory, except so far as the covering and the shutters and some of the minor details are concerned.

The accompanying plan and section, with the following explanation, will perhaps make the construction plain.

The building is circular, the same diameter as the dome—38 ft. 9 in. outside and 36 ft. 3 in. inside. The walls are stone outside and brick inside. The circular wall is 1 ft. 3 in. thick, 7 ft. 4 in. high above the floor, and finishing with an ashlar

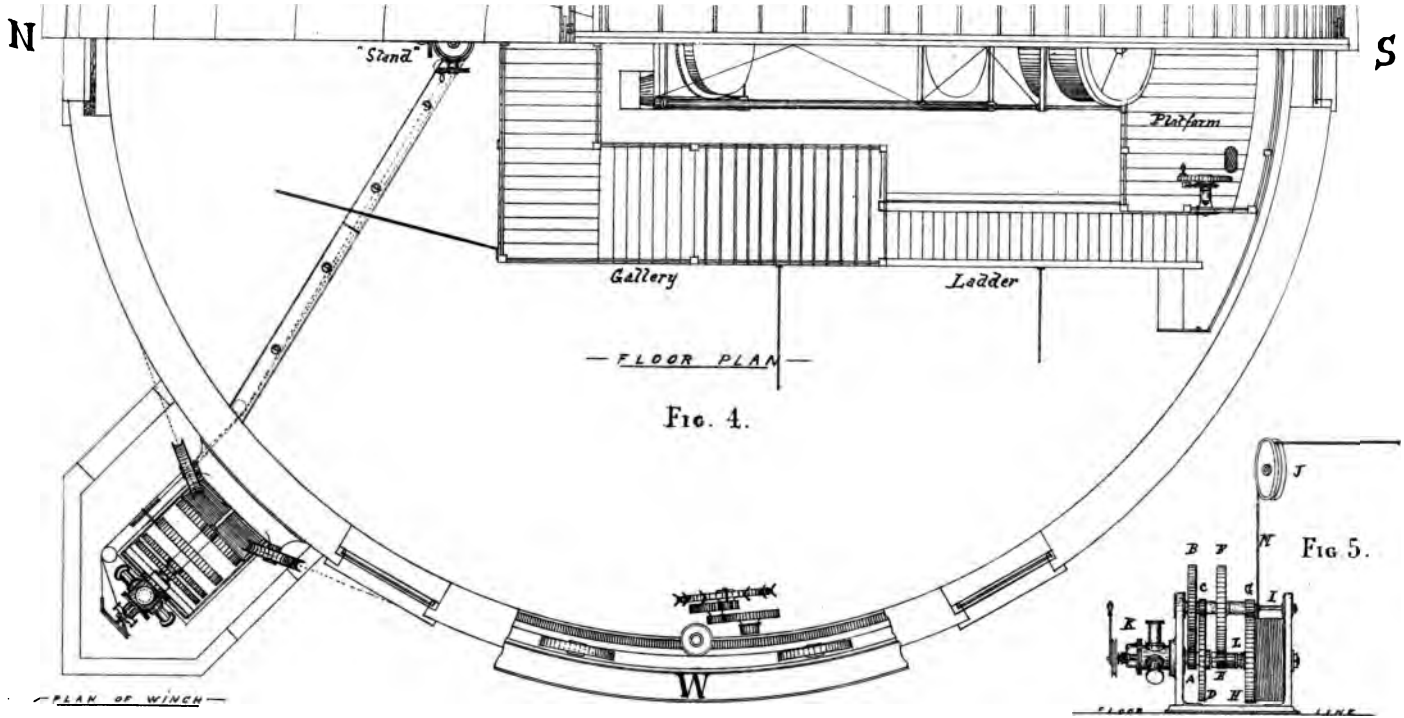


Fig. 4.

Fig. 5.

— SIDE ELEVATION OF WINCH —

course carefully levelled to receive the rail. A north doorway and five windows give access and ventilation. A small room at the N.W. corner, with a flat roof, contains an hydraulic winch for moving the dome.

Fig. 2 shows the top of the wall in section on a larger scale.

The rail is of cast-iron, in 24 segments, planed top and bottom, bolted together and to the masonwork, and carrying a toothed rack all round on the inner side containing 1,392 teeth. Outside is the rain-trough. The foundation ring of the dome is made of $\frac{1}{4}$-inch boiler-plate 21 inches deep, with 4-inch angle-iron top and bottom. To this ring are attached the cast-iron frames in which the 14 large wheels rotate that carry the dome, and also the intermediate wheels that keep the dome in its place horizontally. Outside the ring is a snow-guard, set off from the dome to allow the rainwater to enter the trough. There is also a series of double forks, one of which is shown in fig. 2. These forks carry the two wire ropes, $\frac{3}{8}$-inch in diameter, by which the dome is moved round, so that they do not touch the dome and catch the rainwater from it. To make the dome weatherproof, there is placed immediately above the trough and between the ring and the rail a flat strip of galvanised iron attached to the ring, and from the rail a similar strip of felt cloth covering the iron plate. Two stout parallel girders 6 feet apart run from one side of the dome to the other to support the shutters, and form the opening of the dome. These girders are made of $\frac{1}{4}$-inch boiler-plate 11 inches deep, with 3-inch angle-iron both sides, top and bottom, up to the north side of the opening. Along the opening the girders are 17 inches deep, as shown in section, fig. 3, and extend beyond the shell of the dome to form the sides of the opening. These girders are attached to the ring of the dome by angle blocks, as shown in fig. 1 to the north. The foundation ring is divided into 24 equal parts. From 23 of these rise 2-inch T-section wrought-iron ribs bound together by three $1\frac{3}{4}$-inch angle-iron rings, as shown in fig. 1. The 206 sheets of galvanised iron $\frac{1}{12}$-inch thick which form the covering of the dome are riveted to the ribs as well as to each other with 11,000 rivets. The two shutters are parallel, and open horizontally, and are carried at each end by pullies on rails.

Each shutter is opened by a system of shafting, as shown in fig. 1. The shafting is carried up the sides of the opening on each girder, and the lengths are connected by bevil-wheels. Four cogwheels on the shafting work into four racks upon the shutter. The two systems of shafting are connected together at the bottom of the opening by a cross-shaft and bevil-wheels. A worm-wheel upon the cross-shaft, with worm and handle, as shown in fig. 1, enable both shutters to be opened and closed simultaneously in one minute each way. The shutters are shown in section, fig. 3, both closed. The sections are broken to save room. A trough is formed by angle-iron in one of the shutter ribs to catch any rain that may drive in. This trough is partly

packed with tarred gaskin to make a tight joint with the other shutter when closed. In addition to the outer shutters a light shutter 9 feet by 6 feet is carried between the girders at the zenith and rolled back to north when not required. This shutter gives additional protection to the delicate parts of the instrument, and also shuts out the zenith when not required. It is omitted in the drawing, to avoid complication. The rods which connect the shutter-girders form steps for reaching the top of the dome (see fig. 4).

To enable the observatory to be worked with ease by one observer, an hydraulic winch is placed outside the main wall at the N.W. corner. Figs. 4 and 5 show this in plan and elevation. The winch is constructed as follows. Upon a cast-iron bed plate at each end are bolted two vertical frames. These frames carry two parallel shafts, one over the other. The upper one is fixed, forming a stay to the frames. The lower one is driven by the 3-cylinder water-engine *K*, with cylinders 3 inches diameter and 5 inches stroke, fig. 5. The gearing is in four couples, *A*—*B*, *C*—*D*, *E*—*F*, *G*—*H*, numbered respectively 23—109, 23—109, 16—77, 16—77. *A* is the only wheel keyed fast to its shaft. *B*, *C* and *F*, *G* are pairs, moving freely round together on the upper shaft. The pinion *E* slides on the lower shaft, and can be coupled either to wheel *D* or to a block, *L*, which is keyed fast to the shaft, or remain idle between the two. When the pinion *E* is coupled to *D* then all four sets of wheels are at work, and $5\frac{1}{2}$ revolutions of the water-engine will turn the dome round once in 24 hours. When the pinion *E* is coupled to the block *L* only *E*—*F*, *G*—*H* are at work; *A*—*B*, *C*—*D* run idle, and 72 revolutions of the engine will turn the dome round once in 5 minutes. It is obvious that any intermediate speed can be obtained. The wire ropes are fastened at each end upon the drum and dome respectively. As one rope winds on to the drum the other winds off. The pulley *J* is out of place in the drawing. The rope *M* should come to the middle of the drum. Pullies are placed at *M* to take up any slack there may be in the ropes, but are not shown, to avoid complication.

The valve of the water-engine is connected by wire cords under the floor with the stand on the north side of the telescope. The coupling lever of the pinion *E* is also connected in the same manner, so that the speed and direction of the rotation of the dome can be controlled from the floor of the observatory.

The arrangements for supporting the observer at the eye-piece of the reflector are as follows. A substantial wooden gallery, shaped like the letter U, with railings inside and out, is suspended from the top of the dome and stayed laterally with iron rods, as shown in figs. 1 and 4. Two stout ladders descend from the south ends of the U-gallery to within 15 inches of the floor of the observatory. The lower ends of the ladders are firmly connected together, and also suspended from the dome.

Each ladder has an outside railing. Between the ladders is placed the movable platform, with a triangular frame at each end, carrying rollers resting upon cast-iron rails on the inner side of each ladder, and supported by two balance weights, one of which is shown in fig. 1. On the under-side of each rail is a rack. A shaft with pinions at each end gearing into the racks is carried by bearings under the platform. This shaft is turned by an endless chain and handle upon the platform, as shown in figs. 1 and 4. A safety-catch fitting into a notched wheel upon the shaft prevents the platform from falling with two or more persons upon it. The catch is raised by the left foot upon the plate, shown in fig. 4 close to the hand-wheel. The mechanism is indicated in fig. 1. The platform is balanced to carry one person, and is easily raised and lowered.

The mechanism for opening the shutters is worked from the platform. Two light cords are carried up from the stand over pulley-blocks on the west side of the gallery and platform, so that the observer by pulling the cords can control the winch and move the dome without leaving the eye-end of the telescope in whatever position it may be. Should the water-supply be cut off from any cause, the winch drum *I* is set free by sliding the pinion *G* out of gear with *H*, and the dome is moved by the hand-rope gearing shown due west, fig. 4. An endless rope passes over the large wheel, and the cog-wheels numbered 16–72, 24–84, 17, are thrown, with No. 17, into gear with the rack upon the wall of the observatory. The stud brackets (not shown, to avoid complication) carrying the hand-gear wheels are attached to the foundation ring of the dome. By this means the dome can be easily moved through 90° by one person in 5 minutes. The rack and hand-gear might be dispensed with provided a handle within the observatory was connected by a shaft and pinion with the gearing of the winch outside.

In order to preserve the telescope from damp, hot-water pipes are brought in at the east side of the observatory under the floor and carried round the foundation of instrument, as shown in fig. 1. The circulation can be cut off at once, and the warm water in the pipes replaced by cold.

The total area for ventilation when all is open is equal to $\frac{1}{3}$th the area of the dome. The water-engine can be utilised to facilitate the ventilation of the observatory, if necessary, by driving a small fan.

The weight of the dome is about 14 tons. The weight of the platform, steps, and gallery (about $1\frac{1}{2}$ ton) is additional to this. 7 lbs. on the endless rope of the hand-gear will move the dome.

The construction and erection of the dome has been ably carried out by Messrs. Clapham Bros., of Keighley, Yorkshire, especially as it is the first astronomical dome which they have constructed.

I hope in a future paper to give some account of the telescope and its work.

Note on the visible Spectrum of the Great Nebula in Orion.
By Ralph Copeland, Ph.D.

When examined with a sufficiently powerful spectroscope provided with a slit, the light of the Great Nebula is chiefly separated into the three well-known lines characteristic of most gaseous nebulæ. There is also a fourth line, which is generally admitted to coincide in place with the third great line of the hydrogen spectrum. Towards the end of 1886, however, when the nebula was first studied at Dun Echt with an exceptionally suitable spectroscope, a long stretch of continuous spectrum was detected, embracing the three brighter lines and terminating somewhat abruptly a little above D, in W.L. 570, or thereabouts. In the dark space below this a faint but apparently well-defined line was discovered on December 28, 1886. The first measures, made two days later, indicated that its light was slightly more refrangible than that of the D-lines. It was therefore naturally thought that the line would turn out to be identical with D_3, a supposition which further observations strongly confirmed. The mean wave-length derived from over thirty measures is 587·4, or only 0·1 less than Vogel's position of D_3. The occurrence of this line in the spectrum of a nebula is of great interest as affording another connecting link between gaseous nebulæ and the Sun and stars with bright line spectra, especially with that remarkable class of stars of which the first examples were detected by MM. Wolf and Rayet in the constellation of *Cygnus*.

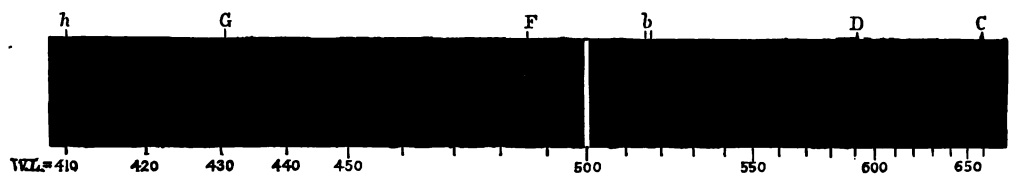
On January 23, 1887, it was believed that traces of an exceedingly faint line could be made out about W.L. 448. If a line of this refrangibility exists, it can probably be photographed more easily than seen.

The following table and diagram show the results of the measures and the general appearance of the spectrum.

Great Nebula in Orion.

	Line (5)	Meas.	(1)	Meas.	(2)	Meas.	(3)	Meas.	eF	Meas.	(4)	Meas.	Continuous Spectrum.
1886, Dec. 28	...	...,	500·7	2	495·8	2	...	...	...	...	434·8	2	
30	585·5	5	...	...	...	...	...	...	...	...	...	...	
1887, Jan. 20	...	...	500·3	2	495·7	2	486·1	3	...	...	434·0	2	Begins 566·2; ends 456·1
23	588·0	8	500·3	1	496·0	1	486·1	2	447·6	1	433·9	3	Begins 564·7.
Feb. 18	589·2	10	...	...	...	...	...	...	...	...	...	...	
Mar. 19	586·9	10	...	...	...	...	...	...	...	...	...	...	
24	...	...	...	...	...	...	...	...	...	...	...	...	Begins 572.0; max. 527·5; ends 462·6
	587·4		500·4		495·8		486·1		447·6		434·2		Begins 567·6 Max. 527·5 Ends 459·4

D_3 Vogel.	D'Arrest's Mean Values.				Watts.
587·5	500·4	495·7	486·1	...	434·0



Visible Spectrum of the Great Nebula in *Orion*.

In conclusion it may be mentioned that on many favourable occasions the spectroscope was carefully adjusted for C, but no trace of that line could be detected in the light of the Great Nebula. On the other hand, the continuous spectrum shows some indications of resolvability into lines or bands.

Lord Crawford's Observatory, Dun Echt:
1888, *June* 2.

Physical Observations of Saturn in 1888.

By Thomas Gwyn Elger.

In continuation of the paper presented at the June meeting last year, I submit the following observations of the planet made with an 8½-inch silver-on-glass reflector by Calver during the months of January, February, March, and April this year, premising that, though the weather generally was not so favourable for the scrutiny of delicate detail as during the spring of 1887, on some four or five nights the atmospheric conditions were especially excellent, and on several occasions, when they were less propitious, spells of very good vision, of longer or shorter duration, were obtained. Eyepieces magnifying 284, 340, and 420 times were employed—the second being found most usually serviceable, though the highest afforded superb views of the planet on suitable nights.

Ring A.—The colour of this ring always appeared on the best observing nights to be lavender-grey, its uniformity and depth of tone, however, varying within wide limits. On some occasions it was either wholly or partially divided, about midway between the outer and inner edge, into two zones—an outer dark zone and an inner light zone, the latter being sometimes evidently the narrower. On March 5, $7^h\ 35^m$ to $9^h\ 0^m$, with superb vision, affording long steady views with powers 340 and 420, the contrast in the shading was very marked, the southern portion from the extremities of both ansæ up to the ball being very much darker than that on the northern half of the ring. On March 21, $9^h\ 15^m$ to $10^h\ 10^m$, it was clearly darker on the *p.* ansa, as was also the case on March 27, $8^h\ 15^m$ to $8^h\ 50^m$. On inferior nights a ruddy or salmon hue was frequently noted in connection with this ring—an appearance which was probably due to atmospheric causes. *Divisions.*—Though a faint, delicate, dark line, presumably Encke's division, was frequently observed last year, even on indifferent nights, not a trace of any dark division was seen this season, except on March 6, 8^h to 9^h, and on March 21. On the former date a faint dark line was glimpsed on the *s. f.* side, and on the latter, between $9^h\ 15^m$ and $10^h\ 10^m$ a similar feature was seen on the *p.* ansa, at a distance of about one-third the width of the ring from its outer edge. A narrow light streak (as was

the case last year) was frequently observed, but on no occasion traced all round. On February 11, $9^h\ 30^m$ to $10^h\ 5^m$, it was seen on the northern side of the *p.* ansa; on February 12, $8^h\ 30^m$ to $9^h\ 10^m$, it was visible for a considerable distance, both on the north and south sides of the *p.* ansa. On March 3, $8^h\ 15^m$ to $9^h\ 15^m$, it was seen well on the *p.* ansa, and less distinctly, near the extremity of the *f.* ansa. On March 5, $7^h\ 35^m$ to $9^h\ 0^m$, it was only traceable on the north side of *p.* ansa. On the following night, 8^h to 9^h, it was once more visible on both ansæ, as on March 3—a faint dark line being noted *s. f.*, as mentioned above. On April 6, 9^h to $9^h\ 45^m$, the light strip was seen *s. p.* It was generally estimated to be rather nearer the outer than the inner edge, though on one or two occasions, notably on February 12, it seemed to be nearer the latter.

Cassini's Division.—This dark band has never impressed me as being perfectly black, or, except as regards its inner edge, well defined. On February 10, $8^h\ 45^m$ to $9^h\ 30^m$, its outer margin on both ansæ seemed "fuzzy," and without any definite limit. The same appearance was noted still more distinctly on February 12, $8^h\ 30^m$ to $9^h\ 10^m$, when ill-defined feathery projections seemed to extend from the outer edge, on E ansa, on ring A. Definition was very good, permitting these features to be steadily seen with both powers, 340 and 420, for some time. On March 5, a still more favourable night, the outer edge was recorded as very badly defined, and projections again noted *s. f.* On subsequent occasions, notably on March 6, 8^h to 9^h, and on March 27, $8^h\ 15^m$ to $8^h\ 50^m$, an evident want of sharpness and distinctness was again remarked in connection with this edge. On many nights, more especially on February 12, March 3, 6, and 21, there was a marked difference between the visibility of the Cassini division on the south and north. From the extremity of either ansa towards the south and up to the ball, it was very much darker than round the north side, where it was scarcely visible at all.

Ring B.—The gradual gradation of shade from the dark inner edge of this ring to the bright zone bordering its outer edge, which was so marked a characteristic on almost every fine night during the early months of last year, has not been on any occasion prominent. The brilliant outer zone, however, has not only given one the impression of being more bright and conspicuous, but has exhibited distinct inequalities in brightness on different segments. On February 7, 9^h to $9^h\ 30^m$, February 10, $8^h\ 45^m$ to $9^h\ 30$, February 11, $9^h\ 30^m$ to $10^h\ 5^m$, February 12, $8^h\ 30^m$ to $9^h\ 10^m$, and March 3, $8^h\ 15^m$ to $9^h\ 15^m$, it was noted as being much more brilliant on the *f.* than on the *p.* ansa. On February 12 this difference in brightness was so remarkable that it could hardly be overlooked by anyone at all accustomed to the examination of planetary detail. On March 5, $7^h\ 35^m$ to $9^h\ 0^m$, it was noted as very brilliant on *s. f.* ansa, less conspicuously so *n. f.*

and *s. p.*, and scarcely traceable *n. p.*, its colour, yellowish white, contrasting with every other feature of the planet. On March 21, $9^h\ 15^m$ to $10^h\ 10^m$, on the contrary, it was brightest on the *s. p.* side, and generally bright on the *p.* side, while it was only just traceable on the opposite ansa. On March 27, $8^h\ 15^m$ to $8^h\ 50^m$, it appeared to be equally brilliant all round. On April 6, 9^h to $9^h\ 45^m$, it was, once more, distinctly brighter on the *f.* side. The width of this brilliant rim was estimated on some nights as being as much as $\frac{1}{3}$, on others as little as $\frac{1}{8}$, the total width of B. No great weight, however, can be given to eye-estimations in this case, as the inner edge of the bright zone was sometimes scarcely distinguishable from the neighbouring portion of the ring The delicate rounding off of the shading from within to the outer bright zone, sometimes giving B the appearance of a solid ring, circular or elliptical in cross-section, which was so remarkable last year, was far less pronounced this season, when on some nights, definition being nearly all that could be desired, with the exception of a dusky crescent-shaped border on one or other of the ansæ, scarcely any difference in depth of tone could be noted in the region between the inner edge of B and that of the brilliant zone on the outer edge of the ring. The widest part of the crescent-shaped shading just mentioned on the inner border of B was at the extreme ends of the ansæ, and was estimated to be about $\frac{1}{4}$ the width of the ring. Its outer limit did not appear to be concentric with the ring, but curved more rapidly, so that this uniformly dusky band died out apparently on either side about midway between the major axis of the ring and the ball. When seen at all, it was generally remarked on the *f.* ansa, and only twice on the *p.* side. It was very distinct on February 10 and 12, March 3, 5, 21, and 27 (all favourable nights) on the *f.* side, and on April 6 and 8 on the *p.* side. On none of these occasions could a trace of a similar band be detected on the opposite ansa.

Ring C.—During the time that this ring was under observation last year, it was generally recorded as more or less dark in tone on both ansæ. The first satisfactory view of it obtained this season (January 29, $8^h\ 40^m$ to $9^h\ 25^m$) exhibited it as light grey in colour on the *p.* ansa, and much more distinct than it was at any time when viewed in the previous year. Its inner edge seemed perfectly regular, and its surface even in tone, except *s. p.* (near the ball), where it appeared to be somewhat darker than elsewhere. The *f.* ansa, however, presented a striking contrast in every respect. Here it was dark and scarcely traceable, and appeared to be separated from B by a narrow sharp dark line all round. On subsequent nights the following observations were recorded:—

February 1, 10^h to $10^h\ 25^m$.—On *p.* ansa light, and greyish in tone. Very obscure on *f.* ansa. Powers 340, 420.

February 3, $7^h\ 30^m$ to 8^h.—Variable definition. Light on *p.* ansa, scarcely visible on *f.* ansa. Power 284.

February 7, 9^h to 9^h 30^m.—Variable definition with occasional steady glimpses. Light grey on *p.* ansa. Inner edge apparently regular. Width estimated as equal to half the space between inner edge of ring and ball. On *f.* ansa very obscure—difficult to make anything of it. Inner edge nowhere traceable. Powers 284, 340.

February 10, 8^h 45^m to 9^h 30^m.—Definition very good at times. Divided from B by a distinct black line, visible only on west ansa. Very obvious and light on *p.* ansa, except on south side for some distance west of the ball, where it was manifestly darker than elsewhere. On *f.* ansa it was dark and only visible in places. At times the inner edge seemed to be indented, but of this I could not be sure as it was so badly defined. Powers 280, 340.

February 11, 9^h 30^m to 10^h 5^m.—Good definition. As on the 10th in *p.* ansa. In *f.* ansa very dark and indistinct. Even at times of best seeing I could only trace the *s. f.* portion of it, the remainder being apparently as dark as the space between the ball and the ring. Powers 284, 340, 420.

February 12, 8^h 30^m to 9^h 10^m.—Good definition. Rather dark, but apparently normal in *p.* ansa. Unequally dark, patchy, in *f.* ansa. The inner edge only visible on *s. f.* side. Powers 340, 420.

March 3, 8^h 15^m to 9^h 15^m.—Good definition. Rather dark in *p.* ansa. Estimated breadth less than space between inner edge and ball. A distinct dark patch, like a notch, visible near the middle of the ansa, broadest on the face of ring, and extending nearly from the inner to outer edge. On *f.* ansa still very dark—only traceable on *s. f.* side. Powers 340, 420.

March 5, 7^h 35^m to 9^h.—Very favourable night, affording splendid glimpses of the planet of long duration. Ring divided from B on *f.* side by a well-defined black space, traceable all round ansa. A similar but broader division noted *s. p.*, being broadest where it abuts on west limb of *Saturn*. In this ansa, however, it cannot be traced on *n. p.* side. Ring somewhat lighter on *p.* than on *f.* ansa, but dark on both. On the former, the dusky spot, seen on March 3, is observed with all the eyepieces, and three or more dark areas are noted on *s.* side of *f.* ansa. Ring not traceable *n. f.* That part of the ring in front of the ball is only slightly darker than dark belt south of the equator and is lighter than any portion of ring A. The limb is visible through it, and it seems wider on the *f.* than on the *p.* side, but as the inner edge is difficult to distinguish from the faint belt behind it, this is doubtful. Powers 284, 340, 420.

March 6, 8^h to 9^h.—Definition not so good as on the 6th, though at times favourable glimpses were obtained. During a spell of good vision after 8^h 30^m I again saw the dusky spot on *p.* ansa, and three or more on south side of *f.* ansa. Powers 340, 420.

March 10, 10^h to 10^h 20^m.—Though an unfavourable night, the difference in depth of tone of the surface on both ansæ was

quite apparent. The ring seemed to be lighter on *p.* ansa, and broader than space between inner edge and ball. Power 340.

Ring C, March 21.

Ring C, March 27.

March 21, 9^h 15^m to 10^h 10^m.—Definition steady, vision good. Inner edge ragged and clearly indented on *p.* side, but indentations not very deep. The ring uneven in colour, though no distinct spots could be made out. On *f.* ansa it was only visible on north side. Powers 340, 420.

March 27, 8^h 15^m to 8^h 50^m.—Definition fairly good. Much lighter on *p.* than on *f.* ansa, where it is scarcely traceable, except on the north side. Inner edge on *p.* ansa scalloped, exhibiting three or four convex projections, and dark patches visible on its surface. Very light where it passes in front of ball. Powers 340, 420.

March 28, 9^h 30^m to 10^h 10^m.—Definition moderate. Light on *p.*, but obscure on *f.* ansa. Scalloped edge again noted on *p.* ansa, one projection, near the centre, being especially deep and prominent. Powers 284, 340, 420.

April 6, 9^h 0^m to 9^h 45^m.—Definition variable. Very light and distinct on *p.* ansa, though somewhat dark on the south near the ball. Scalloped edge again satisfactorily seen with all the powers. Very obscure on *f.* ansa. In front of ball it is certainly wider on *f.* than on *p.* side, as was suspected on March 5. Powers 284, 340, 420.

Belts.—A very marked change both in number, position, and visibility, especially obvious in the region between the South Polar Cap and the dark band south of the bright equatorial zone, has taken place among these delicate features since they were last observed in 1887, tending to show, if it were needed, that the fainter belts are subject to variations, similar in appearance, if not in character, to those noted in connection with the fainter cloud belts of *Jupiter*; while the wide bright equatorial band and the dark belt south of it, though apparently even more persistent than the grosser bands on this planet, would, if it were

possible to examine them under equally favourable conditions, display the same kind of mutability as regards hue and detail. Last year the region south of the bright equatorial zone was marked by a more or less dusky zone, generally recorded as ruddy in colour, and extending to nearly $\frac{1}{3}$ of the apparent distance between the equator and the south limb, and frequently exhibiting long narrow rifts too ill-defined to represent or describe. It was bordered on the north by the darkest and broadest belt on the disc, and on the south by a band nearly as wide but less pronounced. This year this intermediate dusky zone was no longer visible as before, and though the belt which bounded it on the north was still the darkest on the planet, that on the south was only traced as an extremely faint object on the best nights, and was frequently not seen at all, even when atmospheric conditions were favourable.

The belts were usually recorded as follows, commencing from the inner edge of ring C, where it passes in front of the ball:—(1) a faint nebulous band, on some nights scarcely distinguishable from C. Frequently seen to the best advantage near the east and west limb of the planet, where, through the effect of perspective, it appears to rise above the edge of C. (2) A broad bright zone of yellowish hue, generally estimated to be the brightest feature in connection with the planet, extending to a little south of the equator. It was occasionally seen to be mottled with delicate white fleecy spots. (3) A more or less dark band (greyish blue) scarcely $\frac{1}{3}$ the width of 2. Sometimes well-defined on both edges, but far more often noted as harder and sharper on the north than on the south. (4) A greyish region, answering to the dusky ruddy zone seen last year. (5) A very faint belt, representing that which then formed the southern limit of 4, sometimes only partially visible, at other times not seen at all. (6) A uniformly grey region (on which faint belts were occasionally detected), extending to the northern edge of Polar Cap.

On several nights, when definition was favourable, the northern half of bright zone (2) seemed to be distinctly duller than that adjoining 3—notably on March 5—as if a faint broad belt existed between it and 1. Belt 3, on January 29 and February 3, was dark, and sharply defined on both edges. On February 10 it was more sharply defined on the north than on the south, and was estimated as equal in tone to the outer zone of ring A. On February 11 the southern edge was very nebulous. On February 12 both edges were badly defined. On March 21 it was very hard and sharp on the north, while the south edge was ragged. The greyish-blue South Polar Cap appeared to vary in darkness considerably on different nights. From January 17 to February 1 it was recorded as very dusky, but subsequently, from February 3 until March 5, as very light, on some nights scarcely differing in tone from the zone north of it. On the latter date it was very dark near the limb. On

March 21 and 27, it was again described as light. On March 28, $9^h\ 30^m$ to $10^h\ 10^m$, as being decidedly darker on the *f.* side, by the limb, than elsewhere. On April 6 it was of an even grey colour. Detail in the form of ill-defined light markings was frequently seen on band 4, which sometimes seemed to be of a warm ruddy hue. On February 10, at 9^h, a faint narrow band was observed south of 5, which seemed to be slightly inclined to it. On January 29, 5 was only traced from the east limb to about the middle of the disc. The *colour of the ball*, like that of the rings, seems to be a matter depending very much upon the quality of the night. On the best occasions, the yellowish tone of the equatorial region, the pale cinnamon hue of that extending south of the greyish-blue belt, 3, the dull grey of the region south of this, and the lighter bluish-grey or slaty tone of the Polar Cap, were manifest; while on inferior nights the cinnamon hue gave place to a ruddy colour, and the bluish tone of the duskier feature, was far less noticeable.

1. 2. 3. 4.

Shadow of Ball on Rings.—Only two nights were available before opposition on which it was possible to examine the shadow of the ball. On January 9, 9^h to $9^h\ 30^m$, power 340, it was well seen on the *p.* side, and recorded as concentric with the ball. On January 17, $8^h\ 20^m$ to $8^h\ 45^m$, it appeared to be slightly concave on both rings, A and B. It was rather wider south than north, and did not seem so black as the sky or the space between C and the ball. No notch or projection was seen on either evening. On January 29, $8^h\ 40^m$ to $9^h\ 25^m$ (rather more than six days after opposition), and on February 3, $7^h\ 30^m$ to 8^h, the shadow (on *f.* side) was noted as slightly concave, no visible notch or projection being visible with any power. On February 7, 9^h to $9^h\ 30^m$, it was distinctly concave on B up to Cassini's division, but convex on A (fig. 1). On February 10, $8^h\ 45^m$ to $9^h\ 30^m$, it was slightly concave on both rings, with a slight projection at Cassini's division;—seen well with 340 and 420. On February 11, $9^h\ 30^m$ to $10^h\ 5^m$, difficult to detect any concavity in the outline of shadow; notch just glimpsed two or three times. February 12, $8^h\ 30^m$ to $9^h\ 10^m$, slightly concave on A and B, with a notch at Cassini's division. Shadow very black and sharp; traceable on surface of C (fig. 2).

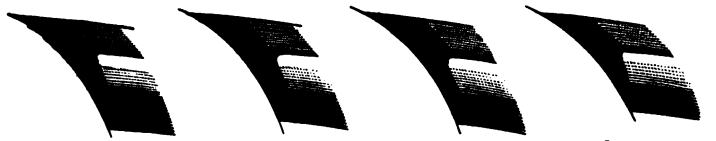
March 3, $8^h\ 15^m$ to $9^h\ 15^m$.—There appears to be a difference in the curvature of boundary of shadow on rings B and A, though it is concave on both. The shadow on B is part of a flatter curve than that on A, the latter widening considerably towards

the edge of the ring. Notch at Cassini's division well seen (fig. 3).

March 5, $7^h\ 35^m$ to 9^h.—Very slightly concave. At times seemed (as on the 3rd) rather more concave on A. Broadest towards the south. Notch at Cassini's division acute and long, appearing to extend some distance along it (fig. 4).

March 6, 8^h to 9^h.—Concave on A and B. Width of shadow in narrowest part equal to $\frac{2}{3}$ of ring A at this place. Notch distinct with all powers.

March 21, $9^h\ 15^m$ to $10^h\ 10^m$.—Very sharp and black, slightly concave on B, but appears to follow the curvature of the ball on A. Easily traced on C. Notch evident, but blunt (fig. 5).



5. 6. 7. 8.

March 27, $8^h\ 15^m$ to $8^h\ 50^m$.—Shadow nearly concentric with ball, but rather wider towards the south. Notch blunt, but obvious (fig. 6).

March 28, $9^h\ 30^m$ to $10^h\ 10^m$.—Shadow, ? slightly concave on B, straight on A. Notch evident (fig. 7).

April 6, 9^h to $9^h\ 45^m$.—? Slightly concave on B, with a blunt protuberance at Cassini's division (fig. 8). April 8, 9^h to $9^h\ 30^m$, as on the 6th.

April 11, $9^h\ 15^m$ to $9^h\ 30^m$.—Though the night was not very favourable, good views were occasionally obtained of the shadow with powers 284 and 340. It appeared to be very distinctly concave both on B and A, the curve on both rings running up to end of notch, which was very blunt.

The objective reality of some of the features just described has, in one or two quarters, been called in question, and an endeavour made to explain them away by suggesting that they are due either to bad definition, distorting eyepieces, or defective vision. No doubt these evils, individually and in combination (especially when associated with a lively imagination), have, ere now, been answerable for the production of remarkable results; but, as regards the foregoing observations, the first two may at once be ignored; as the abnormal appearance of ring C, the peculiarities of the shadow of the ball, and other delicate details were invariably seen to greater advantage in proportion to the goodness of the night for observing purposes; indeed it was, with one or two exceptions, only on favourable nights that it was possible to see the dark areas and ragged edge of A at all. With respect to the eyepieces, they are excellent specimens of the optical skill of the late Mr. Cooke, giving good results on other celestial objects—whether double stars, *Jupiter*, or the Moon—

hence it is inconceivable that they should go wrong on *Saturn*. Only the last objection, therefore, remains—a personal one—defective vision. This, if it has weight in this particular case, would also apply to many who are reckoned as highly-skilled observers. I may especially signalise M. Trouvelot and Dr. Terby. The former, in a valuable paper on *Saturn* (*Comptes rendus*, t. xcviii. p. 968), sums up the results of his own observations with the remark:—"*Les anneaux de cette planète, loin d'être stables, sont, au contraire, essentiellement variables et subissent des changements continuels.*" Since this was written, in 1884, much additional evidence has been forthcoming to support its truth. The existence of *masses sombres* on ring C was announced last year by Dr. Terby, and of indentations on its inner edge by myself; while equally remarkable appearances were recorded by MM. Stroobant and Stuyvaert with the 15-inch equatorial of the Brussels Observatory. This year Dr. Terby has again seen abnormal features. They have also been noted by Major Watson, who has observed dark patches on both ansæ and a serrated edge to ring C, with his fine 13-inch With mirror, at Newbridge, Ireland; by Rev. P. H. Kempthorne, M.A., of Wellington College, who has seen both spots and indentations in connection with C, with an 8½-inch With; and also by M. Gaudibert with an 8½-inch reflector, at Vaison, Vaucluse.

It is perhaps noteworthy that those, with sufficient optical means, who do *not* see them, are more or less desultory observers of the planet, while those just mentioned examined it on every available opportunity. Continuous observation, night after night, doubtless tends to educate the eye, so that it soon becomes so familiar with the object scrutinised, that delicate features, which are either only doubtfully glimpsed or not seen at all by the occasional gazer, are readily detected whenever definition permits.

No telescope of the largest type has of late, so far as I know, been brought to bear upon the rings of *Saturn*. It is to be hoped that this will be done before they become too unfavourably placed for the detection of abnormal details.

Kempston, Beds:
1888, *May* 31.

Observations of Sappho (80). By Professor C. H. F. Peters.

On account of the state of the weather I have not succeeded in obtaining more than the following observations. They are made with the filar micrometer of the 13-inch refractor, power 270, bright wires in dark field. The differences between star and planet have been corrected for refraction.

	H. C. Mean Time. h m s	Δα. m s	Δδ. ″	No. comp.	App. α. h m s	Log. f.p.	App δ. ° ′ ″	Log. f.p.	Comp. *
1888, April 3	9 8 44	+0 55·86	+3 57·0	10	13 28 23·30	9·5447$_n$	−13 36 21·6	0·8311	*a*
4	10 43 35	+3 23·48	−2 44·2	12	27 25·33	9·3057$_n$	13 28 9·9	0·8566	*b*
6	12 23 57	−1 19·90	+1 43·4	15	25 32·39	7·5985	13 11 51·0	0·8644	*c*
8	12 44 15	−1 37·01	−3 11·6	11	23 41·03	8·7924	12 55 32·8	0·8628	*d*

The positions of the comparison stars for 1888·0 are adopted as follows:

	h m s	° ′ ″	
a	13 27 26·18	−13 40 13·9	(Red. to app. place + 1^s·26; −4″·8.) Mean of
	26·06	14·8	W. 13^h·422, incl. syst. corr. −0^s·01; +1″·2.
	26·31	13·0	Sant. (IV.) 1244, incl. syst. corr. +0^s·13; +0″·5.
b	13 24 0·57	−13 25 20·7	(Red. +1^s·27; −5″·0.) Mean of
	0·59	20·8	W. 13^h·356, incl. syst. corr. −0^s·01; +1″·2.
	0·56	22·2	Lam. 1326, incl. syst. corr. +0^s·05; +0″·7.
	0·55	19·0	Sant. (IV.) 1241, incl. syst. corr. +0^s·13; +0″·5.
c	13 26 51·01	−13 13 29·3	(Red. +1^s·28; −5″·0.) Mean by weight of
	51·06	31·8	w. 1, W. 13^h·412, incl. syst. corr. −0^s·01; +1″·2.
	51·10	28·8	w. 2, Altona, *A. N.* vol. xxxiv. (Kam, 2479.)
	50·90	28·6	w. 2, Sant. (IV.) 1243, incl. syst. corr. +0^s·13; +0″·5.
d	13 25 16·75	−12 52 16·0	Cordoba Gen. Cat. 18396. (Red. to app. place + 1^s·29; −5″·2.)

For this last star we find the following older determinations (syst. corr. not included):

	h m s	° ′ ″
LL. 24990	13 25 17·56	−12 52 11·6
W. 13ʰ·378	17·45	13·8
Lam. 1328	16·74	14·9
Sant. (III.) 1550	16·98	17·0

which perhaps indicate a slight proper motion.

On April 6 I have used a star different from the one suggested by Mr. Bryant, since the distance in declination of DM.−12°·3834 (in *Monthly Notices* xlviii. p. 96, the minute of R.A. should be 26ᵐ instead of 25ᵐ) from the planet became inconveniently large for our meridian.

The comparison of the observations with Mr. Bryant's ephemeris, employing the annexed parallaxes, gives the following corrections O−C:

	Parallax.		Corr. Δα.	Corr. Δδ.
	s	″	s	″
April 3	−0·21	+4·0	+6·86	−29·5
4	−0·12	+4·2	6·44	31·1
6	0·00	+4·3	6·69	32·8
8	+0·04	+4·3	6·74	33·9

Litchfield Observatory of Hamilton College, Clinton, N.Y.:
1888, *May* 8.

Observations of Comet a 1888 (*Sawerthal*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

Comet a 1888 (*Sawerthal*).

Greenwich Mean Solar Time.	Observer.	♂−✱ R.A.	Corr. for Par. and Refraction in R.A.	♂−✱ N.P.D.	Corr. for Par. and Refraction in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1888 d h m s		m s	s	′ ″	″		h m s	° ′ ″	
May 11 14 30 1	H. T.	−1 15·22	−0·30	+ 8 12·7	−3·0	6	23 48 25·58	57 52 13·4	*a*
12 13 45 29	T.	−0 36·39	−0·30	+ 1 8·1	−3·6	9	23 50 25·31	57 26 15·4	*b*
13 58 11		+0 11·25	−0·30	+10 41·0	−2·8	2	...	...	*c*
13 13 17 10	H. T.	+2 3·35	−0·30	− 7 48·0	−5·1	4	23 52 28·55	57 0 27·3	*d*
13 18 22		+3 49·12	−0·32	− 1 23·6	−4·1	5	23 52 30·10	57 0 29·3	*e*
13 28 27		−1 15·20	−0·37	+ 6 16·4	−3·1	3	23 52 31·03	57 0 12·9	*f*
15 13 28 56	H. T.	−2 21·50	−0·30	+11 8·1	−3 0	3	23 56 35 90	56 9 28·0	*g*
18 12 29 10	H. T.	−1 16·48	−0·30	− 0 22·3	−4·1	6	...	...	*h*
23 12 24 12	T.	+0 7·25	−0·30	− 2 24·3	−4·6	8	...	...	*i*
31 12 44 43	H. T.	+1 14·63	−0·30	+ 1 34·5	−3·2	4	0 25 41·23	50 16 42·6	*j*
12 48 34		+1 7·93	−0·30	− 5 59·7	−3·8	6	...	...	*k*
12 56 17		−1 48·90	−0·30	−14 17·6	−4·3	2	0 25 39·90	50 16 35·5	*l*
June 3 13 27 45	H. T.	+1 29·10	−0·30	+ 4 14·7	−2·6	1	0 30 26·90	49 19 9·0	*m*
6 11 37 2	H. T.	−0 25·92	−0·20	+ 0 9·5	−3·6	6	...	...	*n*

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1888·0. h m s	N.P.D., 1888·0. ° ′ ″	Authority.
a	Lalande 46883	23 49 41·57	57 43 51·8	Second Armagh Catalogue.
b	W. B. (2) XXIII. 1029	23 51 2·42	57 24 59·0	Weisse's Bessel (2).
c	Arg. Zone +32°, No. 4736	23 50 16	57 17	Bonn Observations, Vol. IV.
d	W. B. (2) XXIII. 1020	23 50 25·91	57 8 8·5	Second Armagh Catalogue.
e	W. B. (2) XXIII. 989	23 48 41·71	57 1 45·1	Weisse's Bessel (2).
f	Lalande 47034	23 53 47·05	56 53 47·7	Greenwich Observations, 1880.
g	W. B. (2) XXIII. 1243–4	23 58 58·15	55 58 8·3	Weisse's Bessel (2).
h	Arg. Zone +34°, No. 5	0 3 47	54 57	Bonn Observations, Vol. IV.
i	Arg. Zone +36°, No. 25	0 11 50	53 5	Bonn Observations, Vol. IV.
j	W. B. (2) 0, 570	0 24 26·97	50 14 59·0	Weisse's Bessel (2).
k	Anonymous			
l	W. B. (2) 0. 656–7	0 27 29·16	50 30 45·1	Second Armagh Catalogue.
m	W. B. (2) 0. 689	0 28 58·05	49 14 44·6	Weisse's Bessel (2).
n	Arg. Zone +41°, No. 109	0 35 14	48 25	Bonn Observations, Vol. V.

Notes.

May 11.—Comet faint. Could only be observed by averted vision. A good deal of haze. Tail traceable for about 4′.
May 12.—Comet very faint.
May 23.—Comet has well-defined nucleus equal to 4th or 5th magnitude star, showing brightly in strong moonlight. No tail visible.
May 31.—Comet about as bright as a 7th magnitude star.
June 3.—Comet a little fainter than a 7·5 magnitude star.
June 6.—Comet about as bright as a 9th magnitude star.

The observations are corrected for parallax and refraction.
The initials H. T., T. are those of Mr. Turner and Mr. Thackeray respectively.

Observations of Comet a 1888 (*Sawerthal*), *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following observations of Comet Sawerthal were made with the Barclay Equatorial, using the ring micrometer with power 100.

1888.	G.M.T.	Comet—Star (Corrected for Refraction only) Δ R.A.	Δ N.P.D.	Comparisons.	Apparent R.A. of Comet.	Log ($p \times \Delta$)	Apparent N.P.D of Comet.	Log ($p \times \Delta$)	Observer.
	h m s	m s	′ ″		h m s		° ′ ″		
May 23	12 43 23	+4 57·27	+6 32·80	8	0 11 58·01	9·3698	53 2 30·58	0·5679	R.

Assumed Place of Comparison Star (*Lalande* 89).

Mean R.A. 1888·0.	Reduction to Apparent Place.	Mean N.P.D. 1888·0.	Reduction to Apparent Place.
h m s	s	° ′ ″	″
0 7 0·96	−0·22	52 55 45·56	+12·22

Authority.

Mean of Radcliffe observations, 1873, 1874, and 1875.

Observer's Remarks.

The coma of Comet is nearly 3′ broad (having widened considerably since May 2), and resembles a pair of wings. The following half of the nucleus forms a well-defined and bright semicircular disc, the preceding part gradually fading down until lost in the nebulosity of the coma. With power 100 the nucleus is equal in brightness to the star near (Arg. Z. + 36°, No. 25), or 8·7 mag., but in the 3-inch finder is nearly as bright as the comparison star (Lalande 89), or 6·8 mag. A faint streak of the tail is visible, and is about 2′ in length. Strong moonlight.

Sketch of Comet *a* 1888 (Sawerthal), May 23, 12h 45m G.M.T. Drawn by Mr. W. H. Robinson, using the Barclay Equatorial, with power 180. (The Star near is Arg. Z. + 36°, No. 25.)

Observation of Comet a 1888 (*Sawerthal*), *made at Launceston, Tasmania.* By A. B. Biggs.

		Comet from Star ♄ 2878.	*Comet N.P.*	
1888.	Greenwich Mean Time.	Diff. R.A.	Diff. N.P.D.	No. of Measures.
	d h m s	s	′ ″	
April	5 7 33 6	−55·25	−2 23·8	4 (all good).

Brightness, ∠ star.

Note.—The whole figure appeared to have assumed quite a ruddy tint as compared with its former appearance—possibly atmospheric, but I think not.

Telescope (8½-inch reflector) previously readjusted.

Observations of Comet a 1888 (*Sawerthal*), *made at Windsor, N. S. Wales.* By John Tebbutt.

The comet, the news of the discovery of which reached me on February 23, has been observed by me on every occasion when the weather permitted. It has throughout been distinctly visible to the unassisted eye, and its nucleus, till towards the close of the period of observation, was brilliant and star-like, and therefore was adapted for accurate pointing. During the last few days the nucleus was considerably elongated, but the point of greatest brightness was clearer for observation. All the positions depend on filar-micrometer comparisons. The first positions for March 7 and 14 were obtained with the 4½-inch and all the rest with the 8-inch equatorial. Fog or cloud has prevented any observation since the morning of the 3rd instant.

Comet a 1888.

1888.	Windsor Mean Time. h m s	Comet — Star. Δ R.A. m s	Δ N.P.D. ′ ″	Comps.	Comet's App. R.A. h m s	Log $\frac{p}{P}$ −	Comet's App. N.P.D. ° ′ ″	Log $\frac{q}{P}$ +	Red. to App. Place. s	″	Comp. Star.
Feb. 27	16 35 34	+ 0 33·93		17	20 2 10·75	8·8746			−2·00		1
27	16 35 34	− 0 5·13	+ 7 21·6	17	20 2 10·93	8·8746	134 20 28·2	9·3789	−2·01	−6·0	2
28	16 34 30	+ 2 13·81	−13 52·0	4	20 6 53·64	8·8651	132 52 32·8	9·4104	−1·95	−5·7	3
Mar. 2	16 26 47	− 0 46·42	+ 2 5·1	9	20 20 1·47	8·8401	128 24 19·1	9·5023	−1·81	−4·0	4
2	17 9 9	− 7 22·11	− 6 48·6	3	20 20 13·75	8·8138	128 21 26·3	9·3576	−1·85	−3·6	5
3	16 42 37	+15 13·61	+ 4 32·6	5	20 24 18·09	8·8234	126 52 7·3	9·4740	−1·69	−4·5	6
3	16 42 37	+ 9 53·77	− 5 31·8	5	20 24 17·93	8·8234	126 52 6·9	9·4740	−1·72	−4·2	7
4	16 35 54	+11 46·48	− 8 5·3	5	20 28 18·57	8·8187	125 21 6·2	9·5123	−1·67	−3·8	8
6	17 8 19	− 0 56·62	− 4 33·3	13	20 36 9·65	8·7818	122 15 14·2	9·4653	−1·65	−2·2	9
7	15 22 27	+ 1 7·90	− 3 5·5	7	20 39 38·31	8·8103	120 49 50·3	9·6974	−1·60	−1·9	10
7	16 43 48	+ 1 20·73	− 8 16·4	21	20 39 51·14	8·7915	120 44 39·4	9·5430	−1·60	−1·9	10
8	16 49 29	− 0 11·15	− 2 15·4	18	20 43 32·88	8·7812	119 12 14·6	9·5468	−1·57	−1·4	11
9	16 46 4	+ 3 48·90	...	9	20 47 9·81	8·7768	...	...	−1·52	...	12
9	16 46 4	+ 2 19·53	+ 0 46·1	9	20 47 9·57	8·7768	117 40 26·7	9·5688	−1·52	−1·0	13
9	16 46 4	+ 0 51·06	...	9	20 47 9·51	8·7768	...	...	−1·53	...	14
10	16 58 56	+ 8 8·05	− 3 42·3	5	20 50 45·18	8·7621	116 7 54·9	9·5600	−1·46	−0·9	15
11	17 14 58	+ 6 52·63	− 6 36·3	5	20 54 17·59	8·7434	114 35 33·8	9·5487	−1·44	−0·4	16
11	17 14 58	+ 5 34·69	...	5	20 54 17·90	8·7434	...	...	−1·44	...	17
11	17 14 58	+ 3 49·73	...	5	20 54 17·54	8·7434	...	...	−1·45	...	18

1888.	Windsor Mean Time.	Comet — Star. Δ R.A.	Comet — Star. Δ N.P.D.	Comps.	Comet's App. R.A.	Log $\frac{p}{P}$	Comet's App. N.P.D.	Log $\frac{q}{P}$	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s	−	° ′ ″	+	s	″	
Mar. 14	16 21 0	+ 6 26·13	− 9 44·0	5	21 4 26·58	8·7628	110 8 6·9	9·6604	− 1·35	+ 0·8	19
14	17 19 48	+ 6 34·09	− 13 21·2	5	21 4 34·54	8·7234	110 4 29·7	9·5896	− 1·35	+ 0·8	19
15	17 19 18	− 3 43·17	+ 8 28·2	8	21 7 55·86	8·7194	108 35 43·4	9·6047	− 1·36	+ 1·7	20
17	17 13 51	+ 5 1·16	+ 2 56·4	9	21 14 32·66	8·7164	105 41 9·6	9·6361	− 1·28	+ 2·1	21
17	17 13 51	− 0 44·61	...	9	21 14 33·10	8·7164	...	...	− 1·30	...	22
18	17 16 59	+ 0 38·15	...	9	21 17 50·15	8·7101	...	...	− 1·27	...	23
18	17 16 59	− 3 24·47	+ 10 38·8	9	21 17 49·98	8·7101	104 15 4·3	9·6447	− 1·28	+ 2·9	24
19	17 31 54	+ 0 49·03	+ 14 59·1	9	21 21 7·85	8·6913	102 49 19·3	9·6464	− 1·24	+ 3·1	25
21	16 57 11	− 0 2·45	− 4 0·8	5	21 27 31·69	8·7184	100 5 23·5	9·6874	− 1·21	+ 3·7	26
21	17 27 3	+ 2 1·73	− 10 20·4	6	21 27 35·84	8·6909	100 3 40·6	9·6720	− 1·20	+ 3·7	27
25	17 35 58	− 0 8·27	+ 8 49·1	13	21 40 22·62	8·6721	94 47 33·8	9·7084	− 1·13	+ 5·1	28
28	17 31 52	+ 5 20·67	− 1 42·9	4	21 49 49·05	8·6593	91 5 59·7	9·7333	− 1·06	+ 5·8	29
29	17 34 32	+ 0 48·44	− 1 8·5	6	21 52 56·55	8·6683	89 54 56·0	9·7412	− 1·06	+ 6·2	30
29	17 34 32	− 2 23·55	− 1 4·6	6	21 52 56·48	8·6683	89 55 0·5	9·7412	− 1·07	+ 6·2	31
31	17 38 38	− 4 17·68	− 11 27·3	5	21 59 9·23	8·6614	87 37 29·6	9·7555	− 1·05	+ 6·8	32
Apr. 1	17 38 25	− 0 57·91	+ 12 21·3	7	22 2 14·25	8·6610	86 31 7·9	9·7621	− 1·02	+ 7·0	33
1	17 38 25	− 2 5·42	...	7	22 2 13·85	8·6610	...	...	− 1·03	...	34
2	17 40 30	+ 5 17·64	− 3 19·1	3	22 5 18·45	8·6577	85 26 8·7	9·7687	− 0·99	+ 7·1	35
2	17 40 30	+ 4 24·02	...	3	22 5 18·11	8·6577	...	...	− 0·99	...	36

Adopted Mean Places of the Stars of Comparison for 1888·0.

Comp. Star.	Mean R.A. h	m	s	Mean N.P.D. °	′	″	Authority.
1	20	1	38·82	134	14	28·6	Stone 10799.
2	20	2	18·07	134	13	12·6	Stone 10803.
3	20	4	41·78	133	6	30·5	Stone 10820.
4	20	20	49·7	128	22	18	Anonymous=8 mag. (Approx. position)
5	20	27	37·71	128	28	18·5	Stone 10965.
6	20	9	6·17	126	47	39·2	Stone 10840.
7	20	14	25·88	126	57	42·9	Cordoba Zone, 22·55.
8	20	16	33·76	125	29	15·3	Stone 10897.
9	20	37	7·92	122	19	49·7	Stone 11038.
10	20	38	32·01	120	52	57·7	Stone 11047.
11	20	43	45·60	119	14	31·4	Wash. Mural. Cir. Zone 132·73.
12	20	43	22·43	117	46	53·3	Stone 11075.
13	20	44	51·56	117	39	41·6	Stone 11088.
14	20	46	19·98	117	35	16·9	Cordoba Zone 10·104.
15	20	42	38·59	116	11	38·1	Stone 11072.
16	20	47	26·40	114	42	10·5	Stone 11116.
17	20	48	44·65	114	39	33·9	Cordoba Zone 32·36.
18	20	50	29·26	114	37	25·9	Arg.-Oeltzen 20973.
19	20	58	1·80	110	17	50·1	Stone 11187.
20	21	11	40·39	108	27	13·5	Greenw. 7 Yr. Cat. 1864, 2411.
21	21	9	32·78	105	38	11·1	Stone 11276.
22	21	15	19·01	105	37	48·1	Arg.-Oeltzen 21323.
23	21	17	13·27	103	59	31·7	Lamont$_2$ 3612.
24	21	21	15·73	104	4	22·6	Schjellerup 8679–80.
25	21	20	20·06	102	34	17·1	Lamont$_2$ 3630.
26	21	27	35·35	100	9	20·6	Lamont$_2$ 3676.
27	21	25	35·31	100	13	57·3	Lamont$_2$ 3666.
28	21	40	32·02	94	38	39·6	Lamont$_2$ 4381.
29	21	44	29·44	91	7	36·8	Glasgow, 5594.
30	21	52	9·17	89	55	58·3	Glasgow, 5639.
31	21	55	21·10	89	55	58·9	Glasgow, 5660.
32	22	3	27·96	87	48	50·1	Glasgow, 5705.
33	22	3	13·18	86	18	39·6	Glasgow, 5703.
34	22	4	20·30	86	26	49·9	Lalande 43221.
35	22	0	1·80	85	29	20·7	Glasgow, 5683.
36	22	0	55·08	85	21	1·1	Schjellerup 9018.

Private Observatory, Windsor, N. S. Wales:
1888, *April* 12.

Note on Comet a 1888 (*Sawerthal*). By L. Becker, Ph.D.

(*Communicated by Dr. Copeland.*)

Along with micrometrical observations of Comet *Sawerthal* with the 15-inch equatorial I have made the following notes on its physical appearance. On May 10 the brightness of the comet was compared in an illuminated field with $*9\cdot4$ mag. DM.+31°, 4984 and $*8\cdot8$ mag. DM.+31°, 4982, and found to be of 9·5 mag. It was an easy object for micrometrical measurement. On May 17·6 the comet appeared in feeble reddish field illumination like a bright, pretty large nebula, hardly brighter in the middle. The north preceding tail was traced for about a minute of arc in rather strong twilight.

On May 21·5 the remarkable change in the appearance of the comet was first noticed. The nucleus was a well-defined object of a few seconds diameter, from which the matter of the comet appeared to flow out towards the north and south preceding sides, falling over in parabolic curves equally to the north and south. The coma was bounded on the preceding side by two curves of less curvature, extending from the nucleus to the north and south. Both parts of the coma appeared of the same size and their light of equal intensity. There was no trace of the tail on the preceding side seen on May 17. A tangent to the following outline of both parts of the coma was found to be in position angle 0°·8. The distance from the north to the south end of the coma was measured = 57″·0 and 59″·5, both wires of the micrometer being moved in order to obtain unbiassed measures free from zero error. In bright field illumination the *nucleus* was estimated 0·1 mag. fainter than $*9\cdot0$ mag., DM. 36°, 14, or = 9·1 mag.

On May 23·6 the position-angle of the tangent to the following boundary of the coma was again measured = 5°·8, 5°·2, 4°·9. The distance of the nucleus from this tangent was measured twice, both wires being altered; it was found = 16″·3 and 16″·5. In bright field illumination the nucleus appeared 0·3 to 0·5 mag. fainter than $*8\cdot7$ mag. DM.+36°, 25, therefore *nucleus* = 9·1. Compared with May 21 the coma did not seem to have changed in form but was not so well defined, perhaps on account of the bad state of the atmosphere.

On March 24 it cleared up about 14^h, but owing to the increasing twilight* only a micrometrical connection with a neighbouring star could be secured. The *nucleus* was larger than previously, and appeared decidedly brighter that $*9\cdot2$ mag. DM. 37°, 39. Since then the sky has been overcast. It may

* With regard to the brightness of the summer twilight, it may be mentioned that in the latitude of Dun Echt (+57° 10′) a short-sighted person can read the preface to the *Nautical Almanac* by the light of the northern sky at midnight on June 21.

perhaps be well to repeat that all the estimates of brightness have been made in an illuminated field.

Lord Crawford's Observatory, Dun Echt:
1888, *June* 4.

The sketch represents the comet as seen with a power of 240 about $13^h\ 30^m$ G.M.T. in twilight without artificial illumination of the field. For the sake of comparison, Prof. A. Hall's drawing of Encke's comet made at Washington in 1871 is reproduced. (Note added July 16, 1888.)

Note on the Glasgow Star Catalogue.
By Professor R. Grant, F.R.S.

It is now five years since the Glasgow Star Catalogue was published, and it is gratifying to me to know that since its first appearance it has been largely used by astronomers in connection with extra-meridional observations of the minor planets and of comets. This circumstance has encouraged me in an endeavour which I formed, shortly after the publication of the Catalogue, to increase its usefulness still further by a reobservation of the stars in the Catalogue, the places of which, when compared with Bessel's places, exhibited larger discordances than can be accounted for by the ordinary errors of observation. The results thus obtained I contemplated incorporating with the earlier results, either in the form of a Supplementary Catalogue or a new edition of the Catalogue itself, unaccompanied, however, by the annual results of the observations, which constituted so large a part of the work published in 1883. The latter is the form which I have decided upon adopting, and the work of the Observatory is now being directed to a scrutiny of the Catalogue and the preparation of the new star places. The auxiliary computations of precession and secular variation are also receiving due attention. The precessions were computed in duplicate and compared, but the secular variations were not computed in duplicate, and errata occur in them which have been pointed out to me by Mr. J. Plummer and others. All the auxiliary computations of the Catalogue are now undergoing a careful revision at the Observatory. My best thanks are due to those astronomers who have kindly made known to me such errata as came

under their notice in the course of their astronomical researches. According to present arrangement the Catalogue, thus revised and strengthened by new observations, will be ready for printing about the close of next year, and will be in the hands of astronomers in the following summer.

The Observatory, Glasgow:
1888, *May* 30.

Errata in Monthly Notices, Vol. XLVIII.

Page 341, May 10—*dele* Apparent R.A. and Apparent N.P.D. of Comet.
Page 342, bottom line—*for* Lalande 46809 *read* Anonymous. *Dele* R.A., N.P.D., and Authority for this star.

Vol. XLVII.

Page 550, June 19—the G.M.T. should be $11^h\,23^m\,55^s$ *instead of* $11^h\,53^m\,55^s$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. SUPPLEMENTARY NUMBER. No. 9

The Ring Nebula in Lyra. By Edward S. Holden, LL.D., Foreign Associate of the R.A.S., Director of the Lick Observatory.

In order to give or to obtain an idea of the power of the 36-inch Clark refractor of the Lick Observatory, it is necessary to compare its performance with that of other telescopes on familiar objects. One of the first objects examined here was the ring nebula of *Lyra*; and I wish to communicate a few particulars regarding its aspect in this telescope, not so much for their strictly scientific value, as to enable others (and myself) to estimate the gain of power by the use of the 36-inch lens.

I had the honour of communicating a note on the same subject to the Society in 1875, which was printed in the *Monthly Notices* for December of that year. I have re-read that note, and the various papers there referred to, and compared them with a pastel drawing of the nebula made by me in 1875 with a power of 400 on the 26-inch refractor at Washington. I find the description of the Washington observations fairly exact, and the pastel drawing to be a good representation of the aspect there. This drawing is deposited in the library of the Lick Observatory. It agrees in general with the drawing made by Mr. Lassell by means of the 4-foot reflector, privately distributed by him in 1860.

I expected that it would be a good representation of the same object as seen here, but in this I was quite mistaken.

The increased brilliancy of the nebula with the larger aperture quite changes its general aspect. It is an entirely hopeless task for me to attempt a drawing of this object as we see it, and therefore I must confine myself to a criticism of my paper of 1875 and to a brief description of the nebula, and wait until we can obtain a photograph of the object which will give the principal details.

Sir John Herschel's figure (*Phil. Trans.*, 1833, plate x. fig. 29) was made with the 20-foot reflector, but it shows little more than can be seen with the 6-inch finder of the large telescope. D'Arrest's two drawings ("Description of the Copenhagen Equatorial," 1861, plate ii. fig. 5; and Sid. Neb. Obs. Hav.) hardly show more of the nebula. They give beside the 14 magnitude star following the nebula (Lassell No. 1), a 19 magnitude (so-called) star, which is Lassell No. 4. Trouvelot's drawing (plate xxxiv. of "Astronomical Engravings, Harvard College Observatory") shows no stars either within or without the nebula. The criticism on this drawing given in my former paper still seems to me to be true; but, on the whole, Mr. Trouvelot's drawing comes nearer to representing what we see here than any other, not excepting my very careful pastel drawing previously referred to. I presume Mr. Trouvelot's picture to have been made with a high magnifying power.

Lord Rosse's drawing (*Phil. Trans.*, 1844, plate xix. fig. 29) shows seven stars outside the nebula, which I identify as follows:—

Lord Rosse. No.	Lassell. No.	Lord Rosse. No.	Lassell. No.
1	2	5	4
2	1	6	7
3	8	7	11
4	3		

These stars were inserted as in some sense tests of the power of the 3-foot reflector, and we may therefore assume that all stars as faint as Lassell's No. 11 were seen although they are not laid down. (Lassell's fourteen stars are numbered in the order of their brightness.)

At the same time Lord Rosse says that the speculum was probably never in first-class condition when this object was viewed. In Lord Rosse's drawing two very faint stars near No. 8 are also given, which were seen with difficulty. These are not seen here. The drawing of the nebulosity also appears to be faulty in many respects. The nebulosity within the ring is not now arranged in streaks parallel to the major axis as drawn by Lord Rosse, and as partially, and very probably erroneously, confirmed by Professor Abbe, and also by myself in 1875. With this exception, the remarks on this drawing in my paper of 1875 appear to be correct in the light of our recent observations.

Mr. Lassell's drawing of 1860 was made with the 4-foot equatorial. He shows thirteen stars without, and one (No. 14) within the nebula, and says that Nos. 12, 13, and 14 "are near the limit of vision with this telescope." "The star a little below the centre of the dark space in the nebula is faint, and from its faintness, in conjunction with my impression that it does not always appear in precisely the same place, I think there may possibly be

two nearly equal stars there, too faint to produce distinct sensations on the retina. I see no other stars whatever in the nebula, nor have I the impression that the brightest parts would break up into stars even with far more optical power."

Mr. Lassell's drawing and my own pastel drawing of 1875 represent quite faithfully the appearance of the nebula in the Washington refractor. He gives thirteen stars outside the nebula, as has been said.

In the *Astronomische Nachrichten*, No. 2139, col. 37, Herr Tempel says that with the Amici telescope of $9\frac{1}{2}$ inches aperture he sees twelve faint stars near the ring nebula, but he gives no places for these. Professor Hall in the same journal, No. 2186, col. 27, gives his measures of nine stars near the nebula. I identify these as follows:—

	Hall. Mag.	Lassell. No.		Hall. Mag.	Lassell. No.
a	13*	1	*f*	13—14	5
b	14	11	f_1	13–14	6
c	13—14	7	f_2	14—15	12
d	12—13	4	*g*	13	8
e	12	3			

Professor Hall says, "I could see no star inside the above ring of stars, nor any star within the ring of the nebula itself. I have been able to see only nine stars near this nebula."

Professor Hall's f_2 is about as faint as any of Lassell's stars outside the nebula, and I am at a loss to understand why he did not include Lassell's No. 13 in his measures, and why he did not see No. 14, which has been well seen by Professor Schultz at Upsala with the Steinheil refractor of $9\frac{1}{2}$ inches, and is seen here with the 12-inch equatorial. Lassell's Nos. 13, 2, 9, 10 clearly belong to the ring of faint stars about the nebula.

The *minimum visible* of a $9\frac{1}{2}$-inch refractor is somewhat fainter than 14 magnitude on Argelander's scale, and it is probable that Herr Tempel's twelve stars were the nine stars measured by Professor Hall, with the addition of Lassell's Nos. 2, 9, and 10.

I now come to the observations made here with the 36-inch telescope by Professor Schæberle and myself jointly. One's first idea is not so much that the aspect is unfamiliar as that it is distinctly different, that its simple structure has suddenly become complex, and finally that the task of depicting it completely is practically impossible by the ordinary methods. On one of the nights of observation Mr. Schæberle and myself were mapping new stars in and about the nebula, and we finally gave up the task not because it was ended, but because it seemed to be endless. The proper method appears to be to photograph the nebula (as we hope to do shortly), and then to add such a description and such measures as may seem to be useful.

* Professor Auwers calls *a* 11·6 magnitude.

It will be a matter of intense interest to us to compare our results with those which have been obtained by the great objectives of Pulkowa and Nice, and with those which will be obtained by the great telescopes which are now making for Mr. Common and others. In order to give a test of the light-collecting power of the 36-inch telescope, I may say that Lassell's Nos. 12, 13 (and of course 14) are easily, distinctly, and steadily seen. There are other stars outside of the ring, of which I will mention only two—Nos. 15 and 16. No. 15 is at the vertex of an isosceles triangle, of which the line 5–12 is the base, and whose altitude is twice its base. No. 15 is north of No. 12. No. 16 (first seen by Mr. Keeler) is at the vertex of an isosceles triangle whose base is the line 3–4, and whose altitude is $1\frac{1}{2}$ time its base. No. 16 is north of No. 3; it is about as faint a star as can be seen here (17 magnitude?).

Our chief attention has, however, been given to stars within the inner dark ring, and to those immersed in nebulosity. Mr. Schæberle (who has first seen most of those within the ring) has used powers of 1344 and less. I have found powers of 672 and less to be best suited for detecting faint stars immersed in the nebulosity or attached to it, as well as for seeing stars within the ring. The stars within the ring and upon the nebulosity are Lassell's No. 14 (which does not always look like a true star, but which is probably not double), and eleven other stars first seen here.

a, *b*, *c*, *d*, *e*, and *h* are within the ring; *g*, *f*, *i*, *j*, *k* are within the nebulosity. The exact position of *h* is somewhat doubtful, and it was only seen by one observer (J. M. S.). The rest have all been repeatedly and steadily seen by both of us. The following diagram gives the approximate positions:—

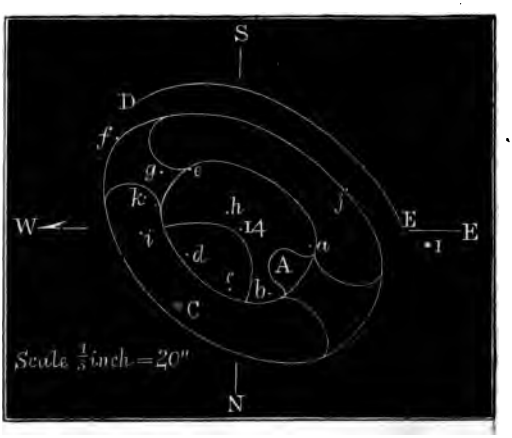


Diagram of the Ring Nebula in *Lyra*, 1888.

If the star 1 be joined with star 14, then—

Star *a* is just north of this line and inside the ring.
„ *b* is 60° north of this line, and just inside the ring.
„ *c* is 95° north of this line, and just inside the ring.
„ *d* is 150° north of this line (prolonged), and inside the ring.
„ *e* is 135° south of this line (prolonged), and just inside the ring.
„ *f* is just preceding the west end of the major axis.
„ *g* as drawn.
„ *h* (?) as drawn.
„ *i* about in the line 14 to 7.
„ *j* is about 25° south of the line 1 to 14, and just outside.
„ *k* about as drawn.

All of the above are true stars apparently; some of them are remarkably sharp and vivid in their light, notably star *f*.

There are also very many other bright points in the nebula which are presumably stars. Many of these could doubtless be fixed in position if there were any object in so doing. As I have said before, both observers thought such a task to be practically endless.

With regard to the aspect of the nebula, it may be said that the north end of the minor axis is much the best terminated. From the whole south edge faint filaments of nebulosity radiate out about as far as the line D E in the diagram. The preceding end of the major axis is the best terminated. There are several bright patches in the nebulosity, especially at the ends of the minor axis. Patch C in the diagram is about in its true position, and is probably the same patch as that seen and described in 1875. Neither the outer nor the inner boundary curves of the nebula are smooth ovals. Inside the ring it is at once seen that the space on the south and preceding side of the line 1 to 14 is darker than the rest. (See my paper of 1875, where this effect was inadequately described, because imperfectly seen.) The heart-shaped space A on the diagram is relatively bright, and has dark channels north and south of it. The space B is the brightest portion inside the ring.

It is interesting to remark that the ring nebula is situated within what Professor Hall calls a ring of faint stars; that its own shape is bounded by two ovals; that the stars within the ring are either central or on the outer oval of the dark space; and that at least two of the stars projected on the nebulosity are in critical positions on the outer oval.

It only requires a moment's examination of the nebula with this telescope to see that no description or drawing can represent the nebula to another as it is seen; but it seems that even so imperfect an account as the foregoing may suffice to show that the great 36-inch refractor is in fact and at present what Mr.

Lick's deed required that it should be, "the most powerful in the world." We have but just begun to use it regularly. In many details it is as yet incomplete, but its performance up to this time has proved to us that, if it is rightly used under suitable conditions, it will produce superb results. The chief object of this note is, as I have said, not so much to add any fact of scientific value to what is known, as to enable a judgment to be made of the power of this latest addition to the family of great telescopes.

Lick Observatory, University of California,
Mount Hamilton: 1888, *July* 15.

Observations of Nebulæ at the Lick Observatory. By Edward S. Holden, Foreign Associate of the R.A.S., and J. M. Schæberle.

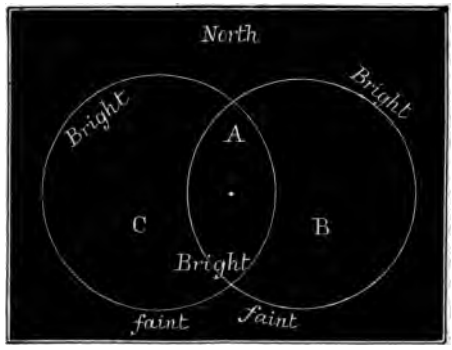
In the intervals of other work the great equatorial has been turned upon some of the more interesting nebulæ. Our observations of the annular nebula in *Lyra* have already been communicated to the Royal Astronomical Society. We beg to communicate herewith further observations upon nebulæ of the planetary class, one of which (37 H. iv., *Draconis*) has proved to be a highly complex and interesting object of a new class.

Helical-Nebula, 37 *H. iv.*, *Draconis*=*G. C.* 4373.

This nebula (of which a drawing is given) was first viewed here on July 27, 1888.

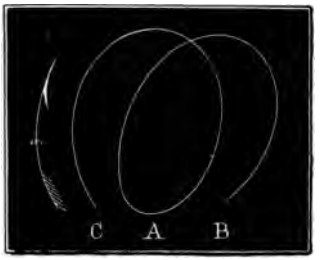
Its bright blue colour and elliptic shape make it one of the most interesting of the class of planetary nebulæ with central stars. It was examined with powers from 270 to 2000 and even higher, and bears magnifying well, losing only its characteristic and remarkable colour with the higher powers.

The nebula is apparently composed of rings overlying each other, and it is difficult to resist the conviction that these are arranged in space in the form of a true helix. The following diagram will illustrate this.



At the first glance the nebula appears to consist of two circles, C and B, which intersect so as to form the space A which surrounds the central star. At the south point of intersection the brightness is approximately twice the average brightness of the circumference; at the north point it is less bright relatively than this. A little attention, however, seems to show that these rings are so arranged that the complete ring C (360°) lies on the hither side (nearer the eye) of the complete ring B (360°); or, if we consider the helix to be generated by the motion of a luminous point in the direction of the arrow, the circumference B s last described.

A then appears to be a part of both B and C. This appearance is perfectly well seen with the central star in exact focus, and it is entirely unmistakable under these conditions with all the eyepieces. It is, however, much better seen with the eyepieces outside of the best focus for the central star. The aspect of the nebula is not changed in this way, but the brighter portions become relatively brighter, narrower, and more sharply defined.



With an eyepiece magnifying 700 diameters one of the observers (E. S. H.) focussed carefully on *Mars*, $\delta = -15°$, and the focussing scale read 2·77 inches; on *Jupiter*, $\delta = -19°$, the reading was 2·75 inches; on the central star of the nebula $\delta = +67°$, 2·76 inches. The nebula itself was well seen with the setting 2·76, but was much better seen when the focus was lengthened by $\frac{44}{100}$ of an inch (reading of scale 3·20 inches): $\frac{44}{100}$ of an inch is about $\frac{1}{1500}$ of the focal length of the objective. A suggestion of Mr. Keeler's that the longer focal adjustment on the nebula was necessary because the central star was essentially red or yellow, while the nebula was unmistakably blue, was tested on August 6, and found to be correct by means of a small pocket spectroscope by Browning. The light of the nebula with a wide slit was monochromatic and blue. The image of the nebula, under these circumstances, was crossed by the continuous spectrum of the central star in which the colours, red and yellow, were plainly visible. With a narrow slit the spectrum of the nebula was seen to consist of three lines.

The places of these lines were first determined by Dr.

Huggins, in his celebrated paper on the "Spectra of Some of the Nebulæ" (*Philosophical Transactions*, 1864, p. 438).

After viewing this object under the circumstances in which it is seen blue here, it is difficult to escape the conviction that in this instance we have the first example of a nebula whose brighter parts are arranged in a true helix. The disposition of the fainter parts has nothing to discredit this conception. In fact it is perfectly easy to conceive the true form of the whole nebula to be that of a cylinder, with the helix of the brighter portions wound upon its outer surface.

We have, therefore, ventured to designate this object as a *helical* nebula—the first of its class—because its brighter portions unquestionably *appear to the eye* in a helical and not simply in a spiral form; and also because it seems to us at least probable that the real disposition of the brighter parts in space *may be* in the form of a helix.

The accompanying figure (Plate 4, fig. 1) is the best representation which we could make. It is highly unsatisfactory at the best; and in order to present more data, extracts from our observing book of July 31, 1888, are given below.

"With power 270, focussed on a star. The central star of the nebula is also in good focus, and the helical shapes are perfectly well seen. They are also seen with the eyepiece inside of focus, and best of all with the eyepiece slightly outside.

"With power 670; the same.

"With other (higher) powers; the same. The higher the power the greater the advantage gained by viewing the nebula slightly out of focus.

"Near the *west* end of the minor axis of A is the darkest part of A; the *south* half of A is the next darkest. The *north* half of A is pretty well filled up with nebulosity.

"The whole of the interior of B is pretty dark; it is darkest towards the *north-west* edge.

"The interior of C is darkest on the *east* and *south* sides."

Circumferences.

"The brightest part of the nebula is about 20° at the *south* extremity of A. The next brightest is about 40° in the *north-west* edge of B. The third brightest part of the circumference begins at the *north* point of A, and extends about 70° towards the *north-east* (in C). Beyond that point the circumference of C is rapidly fainter."

"Starting from the point where C and A join, at the *south*, the first 30° of the circumference is faint; the next 40° fairly bright; then comes a fainter portion; and then the circumference is bright till it joins A at the *north*, where C seems to overlie A."

"The *east* half of the circumference of A is pretty bright as far *north* as the central star, and the rest of the way it is very

37 H.IV.Draconis.

1 H.IV Aquarii, 1888 Aug 2.

E. S. Holden del.
W.H. Wesley lith

West, Newman & C

faint. The *west* half of the circumference of A is pretty faint for the first 30° or more, commencing at the north point; and then pretty bright down to the *south* point of A."

"The circumference of B is faint and diffused from the *south* point of A to the *west* end of the major axis of the nebula; from the latter point for 70° or so it is quite bright, and fainter again before it re-joins A at the *north*."

The outlying nebulosity is about as drawn, only that it is relatively too bright in the sketch.

The only thing specially noteworthy with regard to this outlying nebulosity is the dark space lying on the *north-east* side of the whole nebula which separates two spires of nebulous matter.

A star 14 magnitude, north of the nebula in the direction of the minor axis, has a nebulous appendage on its *west* side. The central star is 11 magnitude. Another star is shown in the sketch close *south-following* the circumference of B. A node of nebulosity or a faint star is obvious in the brightest part (the *north-west* part) of the circumference of B.

"The longest diameter of A makes an angle of about 25° with the minor axis of the whole nebula, and is inclined towards the *west* at its *north* extremity."

The foregoing notes, together with the sketch, will probably serve as a sufficient description of this most remarkable of Sir William Herschel's planetary nebulæ, which seems to be the first known example of an entirely new class of objects.

Ring Nebula, 1 H. iv., Aquarii, G. C. 4628.

The accompanying drawing (Plate 4, fig. 2) gives a fair idea of the shape of this truly wonderful object. One of the best general representations of this nebula may be found in Mr. Lassell's paper, *Memoirs of the Royal Astronomical Society*, vol. xxxvi., plate x., figure 37.

The colour is a pale blue. The form of the object is perfectly well seen with the central star in focus. It is a little better seen by moving the eyepiece outside of focus until the central star almost disappears.

None of the shapes are changed by this process, but the bright central ring becomes narrower, relatively brighter and better defined, and the circular mass in which the central ring seems to lie does not lose any of its characteristics.

The central oval is not bounded by a smooth curve. It looks like an elastic link which has been warped, so that the preceding one-quarter appears beyond the median plane (further away from the eye); the central one-half appears on the hither side of the median plane (nearer the eye); and the following one-quarter again appears to be beyond the median plane.

To use a very homely comparison, the appearance of this central ring is similar to that of a footprint left in the wet sand of a sea-beach.

The central ring lies upon an oval of much fainter nebulosity, somewhat as drawn. This outer nebulosity is fairly uniform in brightness, except that there is a defalcation of light at its *south-preceding* edge, and one at its *north-following* edge, as drawn. The latter is very remarkable as seen, but it is very imperfectly depicted in the sketch. A dark band lies just *north* of the bright central ring, and one not quite so dark lies just *south* of the same ring.

The two satellites preceding and following nearly in the major axis of the nebula appear to be faintly connected with the main nebula. They are nebulous patches with a faint central nucleus, which is probably not stellar.

The central ring is brightest in the *s.p.* quadrant, in the *s.f.* quadrant, and in the *n.f.* quadrant, somewhat as drawn. Just following the *south* end of the minor axis the bright circumference becomes suddenly much fainter, as drawn. This defect of light materially aids to give the warped appearance to the surface of the interior oval, and suggests a helical arrangement of the parts.

The interior of the central oval is filled with pretty bright nebulosity at its following end, with diffused nebulosity at its preceding end, and a dark circular space surrounds the central star (by contrast?). This circular space is prolonged in a triangular shape towards the west. The preceding end of the major axis of the central ring is open, somewhat as in the ring nebula in *Lyra*. Besides the central star (or nebulous nucleus?) there is a fainter star (or node of nebulosity?) near the north end of the minor axis of the whole nebula, and two nebulous nodes in the north portion of the brighter central ring. These two nodes form a nearly equilateral triangle with the central star. It is noteworthy that Mr. Lassell, one of the most scrupulously accurate observers, places the central star south of the major axis of the inner oval. We think there is no doubt that this nucleus is now slightly north of this line.

Careful inspection fails to show a decided helical form to the nebulous mass as a whole, yet the analogy of this nebula to 37 H. iv., *Draconis*, is sufficiently striking to deserve mention.

Lick Observatory, Mount Hamilton, 1888.

Results of Observations of Sappho (80) made at the National Astronomical Observatory, Tacubaya, Mexico.

(*Communicated by the Secretaries.*)

1888.	Tacubaya Mean Time.	Comp. Star.	80 $a'-a$.	Log $p\Delta$.	$\delta'-\delta$.	Log $p\Delta$.	No. of Comp.
	h m s		m s		′ ″		
Mar. 31	11 34 32·9	*19	−1 10·41	9·271$_n$	+3 48·91	+0·676	10:10
Apr. 2	12 17 32·7	17	+1 38·20	8·638	−2 08·81	+0·682	12:12
3	10 55 48·2	17	+ 48 20	9·386	+5 01·59	+0·664	15:15
4	11 21 38·9	14	+3 18·48	9·234	−1 59·27	+0·672	11:11
5	10 03 36·9	14	+2 27·28	9·525	+5 24·44	+0·644	10:10
9	10 23 38·3	15	−2 30·84	9·397	+4 48·96	+0·654	9:9
10	10 15 57·2	13	+ 15·33	9·408	−3 30·44	+0·660	14:14
16	10 52 01·7	9	+1 43·50	9·010	−1 07·93	+0·657	8:8
19	10 13 51·3	8	+ 36·90	9·200	+3 29·42	+0·648	10:10
24	11 08 04·1	5	− 54·98	8·526	+ 13·64	+0·644	15:15

Observer: J. Valle.

Comparison Stars.

1888.	Star.	Mag.	Mean R.A.	Red. to App. Place.	Mean Dec.	Red. to App. Place.	Authority.
			h m s	s	° ′ ″	″	
Mar. 31	*19	7·8	13 32 01·61	+1·22	−14 01 16·2	−4·24	Paris 1855, 1879
Apr. 2	17	8·9	27 26·12	+1·26	−13 40 13·5	−4·69	Weisse, Santini
3	17	8·9	27 26·12	+1·27	−13 40 13·5	−4·80	„ „
4	14	8·9	24 0·46	+1·28	−13 25 21·0	−5·06	„ „
5	14	8·7	24 0·46	+1·29	−13 25 21·0	−5·16	„ „
9	15	7	25 16·70	+1·30	−12 52 15·0	−5·33	Gould, Paris 1870
10	13	9·5	21 35	+1·29	−12 35·5	−5·50	D.M. −12° 3819
16	9	9·2	14 28	+1·32	−11 46·7	−6·04	D.M. −11° 3493
19	8	7·5	12 56·35	+1·33	−12 25 30·0	−6·29	Weisse, Santini
24	5	2·7	13 10 03·98	+1·31	−10 38 50·2	−6·37	Paris 1882

Tacubaya: June 14.

* The numbers refer to Mr. Bryant's list of comparison stars published in the January number of the *Monthly Notices* (vol. xlviii. pp. 95, 96).

Observations of Sappho 80 *with the South Equatorial and*

(*Communicated by R. L. J.*

1888.	Melbourne. Mean Time.			O−✱. Δ α.		Δ N.P.D.			Planet. App. α.			Log p×Δ.	App. N.P.D.			Log. p×Δ.
April	h	m	s	m	s	′	″		h	m	s	s	°	′	″	″
7	12	0	44·0	+0	28·30	+ 0	31·7		5	13	25	12·04	−8·606	103	8	45·2	+0·565
8	10	7	1·0	−0	22·76	− 6	56·2		5	13	24	20·98	9·406	103	1	17·4	0·594
8	10	38	25·1	−0	58·10	+ 8	49·5		5	13	24	19·76	9·294	103	1	8·9	0·582
10	10	11	20·8	+2	48·30	− 7	28·4		5	13	28	6·17	9·379	102	44	51·1	0·594
10	10	40	37·2	+1	7·90	+ 0	48·3		5	13	22	28·43	9·239	102	44	38·4	0·583
11	10	35	21·0	+0	12·19	− 7	29·8		7	13	21	32·73	9·241	102	36	20·4	0·585
12	10	58	10·3	+0	9·37	− 0	31·2		8	13	20	36·12	9·076	102	27	46·8	0·581
13	9	27	17·8	−0	43·29	− 7	54·1		10	13	19	43·46	9·448	102	20	23·9	0·609
15	9	52	34·0	−2	58·00	− 4	54·6		5	13	17	51·46	9·339	102	2	38·5	0·600
15	10	35	29·0	+1	35·57	+ 2	42·2		5	13	17	49·83	9·131	102	2	19·9	0·589
16	8	48	45·4	+0	44·23	− 5	21·6		5	13	16	58·49	9·504	101	54	16·1	0·624
16	9	27	29·3	+0	42·70	− 5	36·2		5	13	16	56·96	9·406	101	54	1·5	0·609
16	9	44	13·1	+0	41·94	− 5	41·8		5	13	16	56·20	9·352	101	53	55·9	0·603
16	10	30	11·9	+2	22·05	+ 7	1·5		3	13	16	54·65	9·134	101	53	46·2	0·591
19	9	27	59·5	+1	15·38	+ 2	33·4		15	13	14	12·62	9·357	101	28	10·2	0·609
19	10	21	46·1	−0	22·20	−18	53·5		3	13	14	10·40	9·092	101	27	51·3	0·596

Melbourne Observatory:
1888, *August* 21.

Dark-field filar Micrometer, at the Melbourne Observatory.

Ellery, F.R.S., Director.)

Red. to App. Place.		Comparison Star. α 1888·0.			N.P.D. 1888·0.			Authority.	
s	″	h	m	s	°	′	″		
+1·28	+5·1	13	24	42·46	103	8	8·4		Melbourne Transit-Circle
+1·28	+5·2	13	24	42·46	103	8	8·4	Anonymous	do.
+1·28	+5·2	13	25	16·58	102	52	14·2	Lal. 24990	do.
+1·29	+5·3	13	25	16·58	102	52	14·2	Lal. 24990	do.
+1·29	+5·4	13	21	19·24	102	43	44·7	Lal. 24888	do.
+1·30	+5·5	13	21	19·24	102	43	44·7	Lal. 24888	do.
+1·31	+5·6	13	20	25·44	102	28	12·4	Lal. 24870	do.
+1·31	+5·6	13	20	25·44	102	28	12·4	Lal. 24870	do.
+1·32	+5·7	13	20	48·14	102	7	27·4	i Virginis	do.
+1·32	+5·9	13	16	12·94	101	59	31·8	Lal. 24773	do.
+1·32	+5·9	13	16	12·94	101	59	31·8	Lal. 24773	do.
+1·32	+5·9	13	16	12·94	101	59	31·8	Lal. 24773	do.
+1·32	+5·9	13	16	12·94	101	59	31·8	Lal. 24773	do.
+1·32	+6·0	13	14	31·28	101	46	38·7	D.M. −11° 3493	do.
+1·32	+6·2	13	12	55·92	101	25	30·6	Lal. 24689	do.
+1·32	+6·1	13	14	31·28	101	46	38·7	D.M. −11° 3493	do.

Observer, P. Baracchi.

Observation of the Occultation of Saturn by the Moon, 1888, *June* 13. By John Tebbutt.

The occultation of *Saturn* by the Moon on the 13th instant was observed here under unfavourable conditions. The disappearances of three objects were observed at the dark limb in the following order. A star of the $7\frac{1}{2}$ magnitude, afterwards identified as $+19°$ No. 2026 of Argelander's Bonner Sternverzeichniss disappeared at the south limb at $6^h\ 41^m\ 22^s{\cdot}0$, local mean time. Had this star been a few seconds further south it would have escaped occultation. Considering that the phenomenon was almost a graze the star disappeared more suddenly than I had anticipated. The next object which disappeared was a star of the 8th magnitude a few seconds south of the planet's centre, but preceding it by about 9·4 seconds of time. The disappearance occurred at $6^h\ 50^m\ 57^s{\cdot}4$, and as this star could not be found on following evenings in the same position with reference to Argelander's star above referred to, it must doubtless be identical with the satellite *Titan*. *Saturn* was badly defined at the time of its disappearance. The indentation of the ring by the Moon's limb was first noted at $6^h\ 51^m\ 20^s{\cdot}6$. For some seconds before the final disappearance the planet appeared as a bright badly defined double spot just within the lunar limb. The last ray from the planet disappeared at $6^h\ 52^m\ 13^s{\cdot}6$. The time of the planet's actual reappearance could not be observed in consequence of a narrow band of clouds about three degrees above the horizon. When the Moon's bright limb, then boiling violently, emerged from the cloud at $7^h\ 45^m\ 48^s{\cdot}5$, the planet was seen separated from it by a few seconds of arc. As the occultation was shut out from observation with the 8-inch equatorial, the $4\frac{1}{2}$-inch telescope had to be employed.

Windsor, N. S. Wales:
1888, *June* 26.

Observations of Comet Sawerthal taken at the Adelaide Observatory. Lat. 34° 55′ 33″·8 *S.; Long.* 9ʰ 14ᵐ 21ˢ·3 *E.*

(*Communicated by Charles Todd, C.M.G., Government Astronomer.*)

Date 1888 A.M.T.	Name of Ref. Star.	Apparent Position of Reference Star. R.A.	Apparent Position of Reference Star. N.P.D.	Diff. ★′−★ R.A.	Diff. ★′−★ N.P.D.	Correction for Diff. Refrac. R.A.	Correction for Diff. Refrac. N.P.D.	Apparent Position of Comet. R.A.	Apparent Position of Comet. N.P.D.
h m s		h m s	° ′ ″	m s	′ ″	s	″	h m s	° ′ ″
Feb. 23 15 30	...	...	...	...	...	...	...	19 41 10	140 0 35
„ 25 16 0	Argentine 27367	19 53 16·0	137 42 3	−1 4·1	−29 57	...	...	19 52 11·9	137 12 6
„ 27 15 39 36·07	„ 27562	20 2 20·04	134 13 6·03	−0 6·58	+ 7 56·4	·00	+0·2	20 2 13·46	134 21 2·6
„ 29 16 10 17·46	„ 27739	20 9 13·73	131 14 45·2	+1 17·62	+ 7 37·8	·00	+0·2	20 10 31·35	131 22 23·2
Mar. 12 16 19 55·10	„ 28854	20 57 7·49	113 4 50·1	+0 36·96	+ 0 13·3	·00	0·0	20 57 44·45	113 5 3·4
„ 18 16 40 1	„ 29400	21 21 14·45	104 4 25·3	−3 22·95	+10 15·1	−·03	+0·5	21 17 51·47	104 14 40·9
„ 26 16 57 49·96	Weisse 1056	21 46 30·89	93 42 6·7	−2 57·11	−10 38·0	+·03	−0·6	21 43 33·81	93 31 28·1
Apr. 4 17 9 49·42	„ 147	22 9 38·78	83 31 45·1	+1 46·81	−11 55·8	+·06	−0·9	22 11 25·65	83 19 48·4

From the observations of March 12, 18, and 26, the following parabolic elements have been computed by Mr. E. C. Cooke, Assistant-Astronomer.

T = Mar. 16·970 G.M.T.	i = 42° 14′ 36″
π = 245° 19′ 35″	log q = 9·8445376
Ω = 245° 28′ 6″	Motion direct.

Adelaide Observatory:
1888, *May* 14.

Sextant Observations of Comet a, 1888 (Sawerthal), made on board the ship "Alcester." By Captain Leonard C. Dart.

(*Communicated by Lieut. C. W. Baillie.*)

1888, March 22. Position at noon by Dead Reckoning: Lat. 3° 24′ S., long. 88° 32′ E.

4·30 A.M. At $10^h\ 43^m$ G.M.T., comet visible; distant from *Altair* 31° 17′, distant from *Arided* 56° 4′, bearing from the planet *Venus*, W.bN., distant 12° 54′. Tail W.S.W. from nucleus about 2° in length. Sky clouded up at the time of taking bearing and did not get the comet's altitude.

Ephemerides of the Satellites of Saturn, 1888–89. By A. Marth.

In the following ephemerides the five inner satellites are assumed to move in circular orbits in the plane of the ring, the ascending node N and inclination J of which, in reference to the plane of the Earth's equator, are assumed to be

for 1889·0 N = 126°·6663. J = 6°·9887.

P denotes the position-angle of the minor axis of the ring, L+180° the planeocentric longitude of the Earth referred to the plane of the ring, Λ+180° that of the Sun, or Λ−L the difference between the two. The last column contains the values of $\log \nu = 0{\cdot}950 - \log \Delta$, the *Naut. Alm.* values of the distances Δ of the planet from the Earth being so altered as to take the equation of light into account.

Greenwich Noon.	P	L	Latitude of Earth above plane of Ring.	Latitude of Sun above plane of Ring.	Λ−L.	Log ν.
1888.	°	°	°	°	°	
Oct. 19	353·030	143·253	−14·114	−16·536	−5·449	9·973631
24	·045	143·582	13·980	16·570	5·602	·977211
29	·059	143·876	13·862	16·403	5·719	·980917
Nov. 3	353·071	144·133	−13·761	−16·336	−5·799	9·984729
8	·082	·350	13·678	16·269	5·840	·988621
13	·090	·526	13·614	16·202	5·840	·992567
18	·096	·661	13·570	16·135	5·799	9·996539
23	·100	·754	13·545	16·068	5·716	0·000509
28	·102	·804	13·540	16·000	5·590	·004448
Dec. 3	353·102	144·810	−13·555	−15·933	−5·420	0·008322
8	·100	·772	13·591	15·865	5·207	·012095
13	·095	·691	13·647	15·797	4·951	·015730
18	·088	·569	13·721	15·729	4·653	·019194
23	·079	·406	13·813	15·661	4·315	·022451
28	·068	144·204	13·923	15·593	3·938	·025468

Greenwich Noon.	P	L	Latitude of Earth | Sun above plane of Ring.		A−L	Log ν.
1889.	°	°	°	°	°	
Jan. 2	353·056	143·966	−14·049	−15·525	−3·525	0·028210
7	·042	143·694	14·189	15·457	3·080	·030642
12	·027	143·393	14·341	15·388	2·605	·032736
17	353·011	143·067	14·503	15·320	2·105	·034468
22	352·994	142·720	14·672	15·251	1·584	·035817
27	·976	142·357	14·847	15·182	1·046	·036767
Feb. 1	352·958	141·982	−15·025	−15·113	−0·498	0·037303
6	·941	141·602	15·204	15·044	+0·055	·037417
11	·924	141·223	15·380	14·975	0·608	·037110
16	·907	140·849	15·552	14·905	1·155	·036389
21	·891	140·485	15·718	14·836	1·691	·035263
26	·876	140·138	15·874	14·766	2·211	·033747
Mar. 3	352·863	139·812	−16·019	−14·697	+2·710	0·031858
8	·850	139·511	16·151	14·627	3·183	·029620
13	·839	139·239	16·269	14·557	3·627	·027063
18	·830	139·000	16·372	14·487	4·038	·024217
23	·822	138·797	16·458	14·417	4·413	·021113
28	·816	138·633	16·527	14·347	4·750	·017784
Apr. 2	352·811	138·509	−16·578	−14·276	+5·046	0·014262
7	·808	·426	16·610	14·206	5·300	·010582
12	·807	·386	16 624	14·136	5·511	·006780
17	·807	·389	16·620	14·065	5·679	0·002890
22	·809	·435	16·597	13·994	5·804	9·998941
27	·812	·523	16·556	13·924	5·887	·994963
May 2	352·817	138 653	−16·497	−13·853	+5·928	·990984
7	·824	138·824	16·420	13·782	5 928	·987033
12	·833	139·034	16·327	13·711	5·888	·983137
17	·843	139·282	16·217	13·639	5·810	·979318
22	·855	139·566	16·091	13·568	5·696	·975595
27	352·868	139 885	−15·951	−13·496	+5·548	9·971988

The values of the apparent equatorial diameter of the ball and of the diameter of the outer rim of the ring depend on Bessel's determinations. The assumed proportion of the polar axis of the ball to the equatorial diameter is 0·900.

In the tables for the five satellites a and b denote the semi-axes of the apparent orbits, $l-\mathrm{L}$ the longitudes of the satellites in their orbits reckoned from the points which are in superior conjunction with the planet's centre or in opposition to the Earth

in longitude. By adding to $l-L$ the value of L from the preceding table, the longitudes l are found. These longitudes, which are the orbital longitudes from the ascending node added to the Right Ascension N of the ascending node, reckoned from the point of the true equinox, are corrected for the equation of light, and depend on the following assumed values, which refer to the time when the light arrives at the distance [0·950]:

Greenwich Noon.	Mimas. l_1	Enceladus. l_2	Tethys. l_3	Dione. l_4	Rhea. l_5
	°	°	°	°	°
1888, Oct. 29	296·415	308·828	261·452	283·796	43·120
Nov. 28	236·222	270·782	222·396	269·846	273·823
Dec. 28	176·031	232·736	183·341	255·896	144·526
1889, Jan. 27	115·841	194·690	144·286	241·946	15·229
Feb. 26	55·651	156·644	105·230	227·996	245·932
Mar. 28	355·462	118·598	66·174	214·046	116·635
Apr. 27	295·274	80·552	27·119	200·096	347·338
May 27	235·087	42·506	348·063	186·146	218 041

The values of P, a, b, and $l-L$ are to be interpolated directly for the times for which the apparent positions of the satellites are required, and the rectangular coordinates x and y, reckoned parallel to the axis of the ring, or, if polar coordinates are wanted, the position-angles p, and distances s, of the satellites in reference to the planet's centre, are then found by means of the formulæ:

$$s \sin (p-P) = x = a \sin (l-L),$$
$$s \cos (p-P) = y = b \cos (l-L).$$

Greenwich Noon.	Diameter of Ball. Equat.	Phase	Polar prec. l.	Axis of Ring. Major	Minor	*Mimas.* a_1	b_1	l_1-L	Diff.
1888.	″	″	″	″	″	″	″	°	°
Oct. 19	17·18	0·039	15·57	39·61	9·66	27·06	−6·60	292·00	1909·81
24	17·32	·041	15·70	39·94	9·65	27·29	6·59	41·81	·85
29	17·47	·043	15·83	40·28	9·65	27·52	6·59	151·66	·89
Nov. 3	17·63	·045	15·97	40·63	9·67	27·76	−6·60	261·55	·93
8	17·79	·046	16·11	41·00	9·70	28·01	6·62	11·48	1909·97
13	17 95	·047	16·26	41·37	9·74	28·27	6·65	121·45	1910·02
18	18·11	·046	16·41	41·75	9·80	28·53	6·69	231·47	·05
23	18·28	·045	16·56	42·14	9·87	28·79	6·74	341·52	·10
28	18·45	·044	16·71	42·52	9·96	29·05	6·80	91·62	·13
Dec. 3	18·61	·042	16·86	42·90	10·06	29·31	−6·87	201·75	·17

Greenwich Noon.	Diameter of Ball. Equat.	Phase prec. l.	Polar	Axis of Ring. Major	Minor	a_1	*Mimas.* b_1	$l_1 - L$	Diff.
1888.	″	″	″	″	″	″	″	°	°
Dec. 8	18·77	·039	17·01	43·28	10·17	29·57	−6·95	311·92	1910·21
13	18·93	·035	17·15	43·64	10·30	29·82	7·03	62·13	·24
18	19·08	·031	17·29	43·99	10·43	30·06	7·13	172·37	·27
23	19·23	·027	17·42	44·32	10·58	30·28	7·23	282·64	·30
28	19·36	·023	17·54	44·63	10·74	30·49	7·34	32·94	·33
1889.									
Jan. 2	19·49	0·019	17·66	44·91	10·90	30·69	−7·45	143·27	1910·34
7	19·59	·014	17·76	45·16	11·07	30·86	7·56	253·61	·36
12	19·69	·010	17·85	45·38	11·24	31·01	7·68	3·97	·36
17	19·77	·007	17·92	45·56	11·41	31·13	7·80	114·33	·37
22	19·83	·004	17·98	45·71	11·58	31·23	7·91	224·70	·38
27	19·87	·002	18·02	45·81	11·74	31·30	8·02	335·08	·36
Feb. 1	19·90	foll.	18·05	45·86	11·89	31·33	−8·12	85·44	·35
6	19·90	limb	18·05	45·87	12·03	31·34	8·22	195·79	·34
11	19·89	·001	18·04	45·84	12·16	31·32	8·31	306·13	·31
16	19·85	·002	18·02	45·77	12·27	31·27	8·38	56·44	·29
21	19·80	·004	17·97	45·65	12·37	31·19	8 45	166·73	·25
26	19·73	·007	17·91	45·49	12·44	31·08	8·50	276·98	·21
Mar. 3	19·65	0·011	17·84	45·29	12·50	30·95	−8·54	27·19	·18
8	19·55	·015	17·75	45·06	12·53	30·79	8 56	137·37	·13
13	19·43	·019	17·65	44·79	12·55	30·61	8·57	247·50	·09
18	19·30	·024	17·54	44·50	12·54	30·41	8·57	357·59	1910·04
23	19·17	·028	17·41	44·18	12·52	30·19	8·55	107·63	1909·99
28	19·02	·033	17·28	43·85	12·47	29·96	8·52	217·62	·94
Apr. 2	18·87	·037	17·14	43·49	12·41	29·72	−8·48	327·56	·89
7	18·71	·040	17·00	43·13	12·33	29·47	8·42	77·45	·84
12	18·55	·043	16·85	42·75	12·23	29·21	8·36	187·29	·79
17	18·38	·045	16·70	42·37	12·12	28·95	8·28	297·08	·74
22	18·21	·047	16·55	41·99	11·99	28·69	8·19	46·82	·70
27	18·05	·048	16·40	41·60	11·85	28·42	8·10	156·52	·66
May 2	17·88	·048	16·25	41·22	11·71	28·16	−8·00	266·18	·61
7	17·72	·047	16·10	40 85	11·55	27·91	7·89	15·79	·58
12	17·56	·046	15·95	40·49	11·38	27·66	7·78	125·37	·54
17	17·41	·045	15·81	40·13	11·21	27·42	7·66	234·91	·51
22	17·26	·043	15·67	39 79	11·03	27·18	7·53	344·42	1909·48
27	17·12	0·040	15·54	39·46	10·84	26·96	−7·41	93·90	

Greenwich Noon.		*Enceladus.*				*Tethys.*			
		a_2	b_2	l_2-L	Diff.	a_3	b_3	l_3-L	Diff.
1888.		″	″	°	°	″	″	°	°
Oct.	19	34·72	− 8·47	57·41	1313·46	42·98	−10·48	10·59	953·26
	24	35·00	8·46	290·87	·48	43·33	10·47	243·85	·29
	29	35·30	8·46	164·35	·52	43 70	10·47	117·14	·32
Nov.	3	35·62	− 8·47	37·87	·57	44·09	−10·49	350·46	·36
	8	35·94	8·50	271·44	·61	44·49	10·52	223·82	·40
	13	36 26	8·54	145·05	·65	44·89	10·57	97·22	·45
	18	36·60	8·59	18·70	·69	45·30	10·63	330·67	·49
	23	36·93	8·65	252·39	·73	45·72	10·71	204·16	·53
	28	37·27	8·73	126·12	·77	46·14	10·80	77·69	·57
Dec.	3	37·60	− 8·81	359·89	·81	46·55	−10·91	311·26	·61
	8	37·93	8·91	233·70	·85	46·96	11·03	184·87	·65
	13	38·25	9·02	107·55	·88	47·35	11·17	58·52	·69
	18	38·56	9·15	341·43	·92	47·73	11·32	292·21	·73
	23	38·85	9·28	215·35	·95	48·09	11·48	165·94	·76
	28	39·12	9·41	89·30	1313·98	48·42	11·65	39·70	·79
1889.									
Jan.	2	39·37	− 9·56	323·28	1314·00	48·73	−11·83	273·49	953·81
	7	39·59	9·70	197·28	·02	49·00	12·01	147·30	·83
	12	39·78	9·85	71·30	·03	49·24	12·20	21·13	·85
	17	39·94	10·00	305·33	·05	49·44	12·38	254·98	·87
	22	40·06	10·15	179·38	·05	49·59	12·56	128·85	·87
	27	40·15	10·29	53 43	·05	49·70	12·73	2·72	·88
Feb.	1	40·20	−10·42	287·48	·04	49·76	−12·90	236·60	·87
	6	40·21	10·55	161·52	·03	49·77	13·05	110 47	·87
	11	40·18	10·66	35·55	1314 01	49·74	13·19	344·34	·85
	16	40·11	10·76	269·56	1313·99	49·66	13·31	218·19	·83
	21	40·01	10·84	143·55	·96	49·53	13·42	92·02	·80
	26	39·87	10·90	17·51	·93	49·36	13·50	325·82	·78
Mar.	3	39·70	−10·95	251·44	·90	49·14	−13·56	199 60	·75
	8	39·49	10·99	125·34	·86	48·89	13·60	73·35	·71
	13	39·26	11·00	359·20	·81	48·60	13 62	307·06	·66
	18	39·01	10·99	233·01	·77	48·28	13·61	180·72	·63
	23	38·73	10·97	106·78	·73	47·94	13·58	54·35	·58
	28	38·43	10·93	340·51	·67	47·57	13·53	287·93	·54
Apr.	2	38·12	−10·88	214·18	·63	47·19	−13·46	161·47	·49
	7	37·80	10 81	87·81	·58	46 79	13·38	34·96	·45
	12	37·47	10·72	321·39	1313·54	46·38	13·27	268·41	953·40

Enceladus.

Greenwich Noon.	a_2	b_2	l_2-L	Diff.
1889.	″	′	°	°
Apr. 17	37·14	−10·62	194·93	1313·49
22	36·80	10·51	68·42	·45
27	36·46	10·39	301·87	·41
May 2	36·13	−10·26	175·28	·36
7	35·81	10·12	48·64	·32
12	35·49	9·98	281·96	·28
17	35·17	9·82	155·24	·25
22	34·87	9·67	28·49	1313·23
27	34·59	− 9·50	261·72	

Tethys.

a_3	b_3	l_3-L	Diff.
″	″	°	°
45·97	−13·15	141·81	953·36
45·55	13·01	15·17	·31
45·14	12·86	248·48	·27
44·73	−12·70	121·75	·23
44·32	12·53	354·98	·19
43·93	12·35	228·17	·15
43·54	12·16	101·32	·12
43·17	11·97	334·44	953·09
42·81	−11·77	207·53	

Dione.

Greenwich Noon.	a_4	b_4	l_4-L	Diff.
1888.	″	″	°	°
Oct. 19	55·04	−13·42	264·77	657·41
24	55·50	13·41	202·18	·44
29	55·97	13·41	139·62	·48
Nov. 3	56·47	−13·43	77·10	·52
8	56·97	13·47	14·62	·56
13	57·49	13·53	312·18	·60
18	58·02	13·61	249·78	·64
23	58·56	13·71	187·42	·69
28	59·09	13·83	125·11	·73
Dec. 3	59·62	−13·97	62·84	·77
8	60 14	14·13	0·61	·81
13	60·64	14·31	298·42	·85
18	61·13	14·50	236·27	·89
23	61·59	14·71	174·16	·92
28	62·02	14·92	112·08	·95
1889.				
Jan. 2	62·41	−15·15	50·03	657·98
7	62·76	15·38	348·01	658·01
12	63·07	15·62	286·02	·03
17	63·32	15·86	224·05	·04
22	63·52	16·09	162·09	·05
27	63·65	16·31	100·14	·05
Feb. 1	63·73	−16·52	38·19	·06
6	63·75	16·72	336·25	·05
11	63·70	16·90	274·30	·04
16	63·60	17·05	212·34	658·02

Rhea.

a_5	b_5	l_5-L	Diff.
″	″	°	°
76·86	−18·74	182·71	398·16
77·50	18·72	220·87	·19
78·17	18·73	259·06	·23
78·86	−18·76	297·29	·27
79·57	18·81	335·56	·31
80·29	18·90	13·87	·36
81·03	19·01	52·23	·39
81·77	19·15	90·62	·44
82·52	19·32	129·06	·48
83·26	−19·51	167·54	·52
83·98	19·74	206·06	·57
84·69	19·98	244·63	·60
85·37	20·25	283·23	·65
86·01	20·54	321·88	·68
86·61	20·84	0·56	·71
87·16	−21·16	39·27	398·74
87·65	21·48	78·01	·77
88·07	21·81	116·78	·79
88·42	22·14	155·57	·81
88·70	22·47	194·38	·82
88·89	22·78	233·20	·83
89·00	−23·07	272·03	·83
89·02	23·35	310·86	·83
88·96	23·60	349·69	·82
88·82	23·81	28·51	398·80

Greenwich Noon. 1889.	*Dione.* a_4	b_4	l_4-L	Diff.	*Rhea.* a_5	b_5	l_5-L	Diff.
	″	″	°	°	″	″	°	°
Feb. 21	63·43	−17·18	150·36	658·00	88·59	−24·00	67·31	398·79
26	63·21	17·29	88·36	657·98	88·28	24·14	106·10	·76
Mar. 3	62·94	−17·37	26·34	·94	87·89	−24·25	144·86	·73
8	62·62	17·42	324·28	·91	87·44	24·32	183·59	·70
13	62·25	17·44	262·19	·87	86·93	24·35	222·29	·67
18	61·84	17·43	200·06	·83	86·36	24·34	260·96	·63
23	61·40	17·40	137·89	·79	85·75	24·29	299·59	·58
28	60·93	17·33	75·68	·75	85·09	24·21	338·17	·54
Apr. 2	60·44	−17·24	13·43	·70	84·40	−24·08	16·71	·50
7	59·93	17·13	311·13	·66	83·69	23·92	55·21	·45
12	59·41	17·00	248·79	·61	82·96	23·74	93·66	·41
17	58·88	16·84	186·40	·57	82·22	23·52	132·07	·37
22	58·34	16·67	123·97	·52	81·48	23·27	170·44	·33
27	57·84	16·47	61·49	·49	80·74	23·01	208·77	·28
May 2	57·29	−16·27	258·98	·44	80·00	−22·72	247·05	·24
7	56·77	16·05	296·42	·40	79·28	22·41	285·29	·20
12	56·26	15·82	233·82	·36	78·57	22·09	323·49	·16
17	55·77	15·57	171·18	·33	77·88	21·75	1·65	·13
22	55·29	15·32	108·51	657·30	77·21	21·40	39·78	398·10
27	54·83	−15·07	45·81		76·57	−21·04	77 88	

Approximate Differences of Right Ascension and Declination between the three outer Satellites and the Centre of Saturn.

Greenwich Noon. 1888.	*Titan.* a_3-A	δ_3-D	*Hyperion.* a_7-A	δ_7-D	*Iapetus.* a_8-A	δ_8-D
	s	″	s	″	s	
Oct. 19	− 9·63	−43·7	...	...	+36·53	+1·5
20	6·02	48·3	...	...	36·60	2·4
21	− 1·55	−46·2	...	...	+36·49	+3·4
22	+ 3·15	37·5	...	...	36·20	4·4
23	+ 7·40	−23·2	...	...	+35·70	+5·5
24	10·54	− 5·5	...	...	34·98	6·5
25	+12·04	+13·1	...	...	+34·05	+7·4
26	11·60	29·6	...	...	32·91	8·3
27	+ 9·23	+41·2	...	...	+31·57	+9·1
28	5·35	45·9	...	...	30·03	9·9
29	+ 0·54	+43·0	+12·58	+36·3	+28·30	+10·7
30	− 4·37	33·1	9·84	46·4	26·39	11·3

Greenwich Noon. 1888.		*Titan.*		*Hyperion.*		*Iapetus.*	
		α_6-A	δ_6-D	α_7-A	δ_7-D	α_8-A	δ_8-D
		s	″	s	″	s	″
Oct.	31	− 8·61	+18·0	+ 5·88	+50·6	+24·32	+11·9
Nov.	1	11·55	0·0	+ 1·15	48·6	22·08	12·5
	2	−12·79	−18·0	− 3·73	+40·9	+19·69	+12·9
	3	12·18	33·4	8·23	28·6	17·17	13·3
	4	− 9·85	−44·1	−11·93	+13·4	+14·53	+13·6
	5	6·13	48·7	14·60	− 2·9	11·78	13·9
	6	− 1·53	−46·3	−16·10	−19·1	+ 8·95	+14·1
	7	+ 3·30	37·3	16·43	33·9	6·05	14·2
	8	+ 7·67	−22·8	−15·64	−46·5	+ 3·09	+14·2
	9	10·88	− 4·8	13·85	56·1	+ 0·10	14·2
	10	+12·38	+13·9	−11·18	−62·2	− 2·89	+14·1
	11	11·89	30·5	7·81	64·4	5·88	13·9
	12	+ 9·43	+42·0	− 3·94	−62·7	− 8·85	+13·6
	13	5·33	46·5	+ 0·20	56·8	11·76	13·3
	14	+ 0·43	+43·3	+ 4·33	−47·1	−14·61	+12·9
	15	− 4·62	33·1	8·16	33·9	17·37	12·4
	16	− 8·96	+17·5	+11·34	−18·0	−20·02	+11·9
	17	11·94	− 0·7	13·52	− 0·4	22·55	11·3
	18	−13 16	−19·0	+14·35	+17·3	−24·94	+10·6
	19	12·49	34·5	13·60	33·1	27·16	9·9
	20	−10·04	−45·2	+11·25	+44·9	−29·21	+ 9·1
	21	6·17	49·6	7·46	51·2	31·07	8·2
	22	− 1·41	−47·0	+ 2·73	+51·1	−32·73	+ 7·3
	23	+ 3·57	37·5	− 2·35	44·8	34·18	6·3
	24	+ 8·03	−22·5	− 7·20	+33·5	−35·40	+ 5·3
	25	11·29	− 4·1	11·34	18·7	36·39	4·3
	26	+12·77	+15·1	−14·46	+ 2·1	−37·14	+ 3·2
	27	12·17	31·9	16·41	−14·7	37·65	2·1
	28	+ 9·56	+43·4	−17·13	−30·5	−37·91	+ 1·0
	29	5·33	47·7	16·67	44·2	37·92	− 0·1
	30	+ 0·20	+44·1	−15·11	−55·1	−37·68	− 1·3
Dec.	1	− 4·98	33·3	12·60	62·6	37·20	2·4
	2	− 9·40	+17·1	− 9·30	−66·3	−36·47	− 3·6
	3	12·40	− 1·7	5·40	65·8	35·50	4·8
	4	−13·56	−20·4	− 1·14	−61·0	−34·31	− 5·9
	5	12·77	36·2	+ 3·21	52·2	32·89	7·0
	6	−10·16	−47·0	+ 7·34	−39·5	31·25	− 8·1

Greenwich Noon. 1888.	*Titan.* a_6-A	δ_6-D	*Hyperion.* a_7-A	δ_7-D	*Iapetus.* a_8-A	δ_8-D
	s	"	s	"	s	"
Dec. 7	− 6·10	−51·2	+10·90	−23·6	−29·41	− 9·2
8	− 1·17	−48·1	+13·51	− 5·7	−27·38	−10·2
9	+ 3·95	38·1	14·80	+12·9	25·18	11·2
10	+ 8·50	−22·3	+14·50	+30·2	−22·81	−12·1
11	11·76	− 3·1	12·48	43·9	20·29	12·9
12	+13·16	+16·6	+ 8·91	+52·3	−17·63	−13·7
13	12·41	33·8	+ 4·20	54·1	14·85	14·4
14	+ 9·60	+45·4	− 1·05	+49·3	−11·98	−15·1
15	+ 5·17	49·4	6·20	38·8	9·02	15·6
16	− 0·14	+45·3	−10·73	+24·2	− 6·00	−16·1
17	5·45	33·7	14·28	+ 7·2	− 2·93	16·5
18	− 9·92	+16·7	−16·63	−10·5	+ 0·16	−16·7
19	12·88	− 2·9	17·71	27·4	3·27	16·9
20	−13·94	−22·3	−17·55	−42·6	+ 6·37	−16·9
21	12·98	38·5	16·21	55·0	9·45	16·9
22	−10·17	−49·3	−13·84	−64·0	+12·48	−16·7
23	5·91	53·2	10·59	69·0	15·44	16·4
24	− 0·80	−49·6	− 6·67	−69·8	+18·32	−16·0
25	+ 4·45	38·8	− 2·31	66·1	21·11	15·5
26	+ 9·04	−22·1	+ 2·22	−57·9	+23·78	−14·8
27	12·25	− 2·0	6·59	45·6	26·32	14·1
28	+13·51	+18·6	+10·46	−29·7	+28·71	−13·2
29	12·57	36·2	13·43	−11·1	30·94	12·2
30	+ 9·52	+47·8	+15·13	+ 8·5	+32·99	−11·1
31	+ 4·87	51·5	15·21	27·4	34·85	9·9
32	− 0·61	+46·7	+13·53	+43·2	+36·51	− 8·6

Approximate Greenwich times of conjunctions of the satellites with the centre of the planet or of their passages in the direction of the minor axis of the ring.

"n" inferior conjunction, or satellite north, moving from the following to the preceding side.

"s" superior conjunction, or satellite south, moving from the preceding to the following side.

In the case of *Titan* and *Iapetus* the approximate distances from the major axis of the ring are added, at which they pass in the direction of the minor axis. In the case of *Iapetus* and of the fixed star of Dec. 12, the conjunctions with the ends of the ring ("f" following, "p" preceding end) are also given.

1888.	h				h				h		
Oct. 21	9·7	Tit. s.	44″	Nov. 10	19·1	Mi. s.		Nov. 23	12·5	Mi. n.	
29	4·2	Tit. n.	42″	11	1·9	En. s.			19·6	Te. s.	
	7·4	Di. n.			13·1	Te. n.		24	2·9	Rh. n.	
	7·9	Te. n.			17·7	Mi. s.			7·5	Di. s.	
	17·9	En. s.			18·3	En. n.			18·3	Te. n.	
30	6·4	Rh. s.			23·9	Di. n.			18·7	En. s.	
	6·6	Te. s.		12	10·7	En. s.		25	16·3	Di. n.	
	10·3	En. n.			11·8	Te. s.			16·9	Te. s.	
	16·2	Di. s.			16·4	Mi. s.		26	9·1	Rh. s.	
31	5·2	Te. n.			19·8	Rh. s.			15·6	Te. n.	
	19·2	En. n.		13	8·7	Di. s.			20·0	En. n.	
Nov. 1	1·1	Di. n.			10·4	Te. n.		27	1·2	Di. s.	
	3·9	Te. s.			15·0	Mi. s.			12·5	En. s.	
	11·6	En. s.			19·6	En. s.			14·2	Te. s.	
	12·6	Rh. n.		14	3·6	Tit. n.	42″		18·2	Mi. s.	
2	2·5	Te. n.			9·1	Te. s.		28	10·0	Di. n.	
	9·9	Di. s.			12·1	En. n.			12·9	Te. n.	
	18·9	Mi. n.			13·6	Mi. s.			15·3	Rh. n.	
	20·5	En. s.			17·6	Di. n.			16·9	Mi. s.	
3	1·2	Te. s.		15	2·0	Rh. n.			21·4	En. s.	
	13·0	En. n.			4·5	En. s.		29	11·5	Te. s.	
	17·5	Mi. n.			7·7	Te. n.			13·8	En. n.	
	18·8	Di. n.			12·2	Mi. s.			15·5	Mi. s.	
	18·9	Rh. s.			21·0	En. n.			18·8	Di. s.	
	23·9	Te. n.		16	2·4	Di. s.		30	2·6	Tit. n.	43″
4	16·1	Mi. n.			6·4	Te. s.			10·2	Te. n.	
	21·9	En. n.			10·8	Mi. s.			14·1	Mi. s.	
	22·5	Te. s.			13·4	En. s.			21·5	Rh. s.	
5	3·6	Di. s.			22·1	Mi. n.			22·7	En. n.	
	14·3	En. s.		17	5·0	Te. n.		Dec. 1	3·7	Di. n.	
	14·7	Mi. n.			8·3	Rh. s.			8·8	Te. s.	
	21·2	Te. n.			11·3	Di. n.			12·7	Mi. s.	
6	1·1	Rh. n.			20·8	Mi. n.			15·1	En. s.	
	9·4	Tit. s.	44″		22·3	En. s.		2	7·5	Te. n.	
	12·5	Di. n.		18	3·7	Te. s.			7·6	En. n.	
	13·3	Mi. n.			14·7	En. n.			11·3	Mi. s.	
	19·8	Te. s.			19·4	Mi. n.			12·5	Di. s.	
7	12·0	Mi. n.			20·1	Di. s.			22·6	Mi. n.	
	15·6	En. n.		19	2·3	Te. n.		3	0·0	En. s.	
	18·5	Te. n.			14·5	Rh. n.			3·7	Rh. n.	
	21·3	Di. s.			18·0	Mi. n.			6·1	Te. s.	
8	7·4	Rh. s.			23·6	En. n.			16·4	En. n.	
	8·1	En. s.		20	1·0	Te. s.			21·2	Mi. n.	
	10·6	Mi. n.			4·9	Di. n.			21·4	Di. n.	
	14·3	Iap. fn.	12″		16·1	En. s.		4	4·8	Te. n.	
	17·1	Te. s.			16·6	Mi. n.			8·9	En. s.	
	21·9	Mi. s.			23·6	Te. n.			19·9	Mi. n.	
9	0·5	En. n.		21	8·5	En. n.		5	3·4	Te. s.	
	1·8	Iap. n.	14″		13·8	Di. s.			6·2	Di. s.	
	6·2	Di. n.			15·2	Mi. n.			9·9	Rh. s.	
	8·3	Di. ♂ Iap.			20·7	Rh. s.			17·8	En. s.	
	13·3	Iap. pn.	17″		22·3	Te. s.			18·5	Mi. n.	
	15·8	Te. n.		22	0·9	En. s.		6	2·1	Te. n.	
	17·0	En. s.			8·5	Tit. s.	45″		10·2	En. n.	
	20·5	Mi. s.			13·8	Mi. n.			15·0	Di. n.	
10	9·4	En. n.			17·4	En. n.			17·1	Mi. n.	
	13·6	Rh. n.			21·0	Te. n.		7	0·7	Te. s.	
	14·4	Te. s.			22·6	Di. n.			15·7	Mi. n.	
	15·0	Di. s.		23	9·8	En. s.			16·1	Rh. n.	

1888.	h		h		h	
Dec. 7	19·1	En. n.	Dec. 16	0·4	En. n.	Dec. 24	5·6	Tit. s. 47″
	23·4	Te. n.		1·1	Tit. n. 45″		5·6	En. n.
	23·9	Di. s.		4·9	Di. s.		9·9	Di. n.
8	7·2	Tit. s. 46″		11·2	Te. s.		14·8	Mi. n.
	11·5	En. s.		14·6	Mi. s.		22·1	En. s.
	14·3	Mi. n.		16·8	En. s.		23·1	Te. n.
	22·0	Te. s.		16·9	Rh. n.	25	13·4	Mi. n.
9	8·7	Di. n.	17	9·3	En. n.		14·5	En. n.
	12·9	Mi. n.		9·9	Te. n.		17·6	Rh. n.
	20·4	En. s.		12·0	Iap. ps. 14″		18·7	Di. n.
	20·7	Te. n.		13·2	Mi. s.		21·7	Te. s.
	22·3	Rh. s.		13·7	Di. n.	26	7·0	En. s.
10	11·6	Mi. n.	18	0·0	Iap. s. 17″		12·0	Mi. n.
	12·9	En. n.		1·7	En. s.		20·4	Te. n.
	17·6	Di. s.		8·5	Te. s.		23·3	Mi. s.
	19·3	Te. s.		11·7	Iap. fs. 20″		23·4	En. n.
	22·9	Mi. s.		11·8	Mi. s.	27	3·5	Di. s.
11	18·0	Te. n.		18·1	En. n.		10·6	Mi. n.
	21·5	Mi. s.		22·6	Di. s.		15·8	En. s.
	21·7	En. n.		23·1	Mi. n.		19·0	Te. s.
12	2·3	$*9^m$pn59″†		23·1	Rh. s.		21·9	Mi. s.
	2·4	Di. n.	19	7·2	Te. n.		23·8	Rh. s.
	4·5	Rh. n.		10·3	Mi. s.	28	8·3	En. n.
	10·1	$*9^m$n.44″†		10·6	En. s.		12·4	Di. n.
	14·2	En. s.		21·7	Mi. n.		17·6	Te. n.
	16·6	Te. s.	20	3·0	En. n.		20·5	Mi. s.
	17·7	$*9^m$fn30″†		5·8	Te. s.	29	16·3	Te. s.
	20·1	Mi. s.		7·4	Di. n.		17·2	En. n.
13	11·2	Di. s.		19·5	En. s.		19·2	Mi. s.
	15·3	Te. n.		20·3	Mi. n.		21·2	Di. s.
	18·7	Mi. s.	21	4·5	Te. n.	30	6·0	Rh. n.
	23·1	En. s.		5·3	Rh. n.		9·6	En. s.
14	10·7	Rh. s.		16·2	Di. s.		14·9	Te. n.
	13·9	Te. s.	22	3·1	Te. s.		17·8	Mi. s.
	15·5	En. n.	23	1·1	Di. n.	31	6·0	Di. n.
	17·3	Mi. s.		1·8	Te. n.		13·6	Te. s.
	20·1	Di. n.		11·5	Rh. s.		16·4	Mi. s.
15	7·9	En. s.		13·2	En. s.		18·5	En. s.
	12·6	Te. n.		16·2	Mi. n.		23·1	Tit. n. 47″
	15·9	Mi. s.	24	0·4	Te. s.			

By means of this list of conjunctions (the continuation of which, together with the continuation of the predicted places of the three outer satellites, will be published in the next number of the *Monthly Notices*) approximate values of the coordinates x and y of the five inner satellites may be easily found for any other time t with the help of the following little table, the argument of which is the interval τ between the time t and the time of the next preceding or following conjunction, the coordinates x and y being expressed in semi-diameters of the planet's equator. The satellites are on the same side, north or south, of the major axis

† The star is W. B. $9^h{\cdot}638$, and its assumed apparent place
$\alpha\ 9^h\ 31^m\ 48^s{\cdot}11$, $\delta + 15°\ 43'\ 2''{\cdot}6$.

of the ring as at the time of the next conjunction, and, as they move in the direction of *decreasing* position-angles, they are in the interval between a north and a south conjunction on the preceding side, and between a south and a north conjunction on the following side of the direction of the minor axis of the ring. They are at their greatest elongations, Mi. 5·7, En. 8·2, Te. 11·3, Di. 16·4, Rh. 27·1 hours before or after the times of conjunction.

τ	*Mimas.*		*Enceladus.*		*Tethys.*		*Dione.*		*Rhea.*	
h	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	x_5	y_5
0	0·0	0·8	0·0	1·0	0·0	1·2	0·0	1·6	0·0	2·2
1	0·9	0·8	0·8	1·0	0·7	1·2	0·6	1·6	0·5	2·2
2	1·7	0·7	1·5	0·9	1·4	1·2	1·2	1·6	1·0	2·2
3	2·3	0·5	2·2	0·8	2·0	1·1	1·8	1·5	1·5	2·2
4	2·8	0·3	2·8	0·7	2·6	1·1	2·4	1·5	2·0	2·2
5	3·1	0·1	3·3	0·6	3·2	1·0	2·9	1·4	2·5	2·1
6	3·1	0·1	3·7	0·4	3·7	0·8	3·5	1·3	3 0	2·1
7	2·9	0·3	3·9	0·2	4·1	0·7	4·0	1·3	3 5	2·1
8	2·5	0·5	4·0	0·0	4·5	0·6	4·4	1·2	4·0	2·0
9	1·8	0·6	4·0	0·1	4·7	0·4	4·8	1·0	4·5	1·9
10	1·1	0·7	3·8	0·3	4·9	0·2	5·2	0·9	4·9	1·9
11					5·0	0·1	5·6	0·8	5·3	1·8
12							5·8	0·7	5·7	1·7
14							6·2	0·5	6·5	1·6
16							6·4	0·1	7·1	1·4
20									8·2	0·9
27·1									8·9	0·0

Observers who are desirous to follow the motions of the satellites will find it of service to lay down the data of the table graphically on a sufficiently large scale, so that, by marking the corresponding times for the night of observing, they may get information about the places of the satellites at a glance.

Careful observations of the position-angles of the satellites at the times of their passing in the direction of the minor axis of the ring afford the best means for determining their orbital longitudes, and will be especially valuable while the apparent orbits are closing in, before they are intercepted by the body of the planet.

The present and the next apparition of *Saturn* are the most favourable for observing the differences of right ascension and declination between *Iapetus* and the centre of *Saturn*, and procuring thereby the best direct data for fixing the elements of

the satellite's orbit. The opportunities for observing the conjunctions of the satellite with the centre of the planet (when it may be preferable to observe position-angles and distances) should not be missed, especially those of the closer conjunctions, Nov. 8–9, and Dec. 17–18.

Ephemeris of the Satellite of Neptune, 1888–89. By A. Marth.

Greenwich Noon.		P′	*a*	*b*	*u*−U	Diff.	U	B
1888.		°	″	″	°	°	°	°
Oct.	19	324·79	16·87	8·52	264·32	612·35	129·20	−30·30
	29	324·58	16·92	8·52	156·67	·31	129·45	30·21
Nov.	8	324·36	16·96	8·51	48·98	·28	129·73	30·11
	18	324·12	16·97	8·48	301·26	·27	130·02	30·00
	28	323·88	16·97	8·45	193·53	·27	130·32	29·88
Dec.	8	323·64	16·95	8·41	85·80	·28	130·61	29·76
	18	323·42	16·91	8·37	338·08	·29	130·88	29·65
	28	323·23	16·86	8·31	230·37	·33	131·11	29·55
1889.								
Jan.	7	323·07	16·79	8·26	122·70	612·37	131·31	−29·47
	17	322·95	16·71	8·20	15·07	·42	131·46	29·40
	27	322·87	16·62	8·14	267·49	·48	131·55	29·35
Feb.	6	322·84	16·53	8·09	159·97	·53	131·59	29·32
	16	322·86	16·43	8·05	52·50	·59	131·56	29·32
	26	322·92	16·34	8·01	305·09	·65	131·48	29·34
Mar.	8	323·03	16·25	7·97	197·74	·71	131·34	29·39
	18	323·19	16·16	7·95	90·45	612·76	131·14	29·36
	28	323·39	16·09	7·93	243·21		130·89	29·55

P′ position-angle of the minor axis of the satellite's apparent orbit, in the direction of superior conjunction.

a, *b*, major and minor semi-axes of the apparent orbit.

u−U, longitude of the satellite in its orbit, reckoned from the point which is in superior conjunction with the planet or in opposition to the earth.

U + 180°, planetocentric longitude of the earth, reckoned in the satellite's orbit from the ascending node on the celestial equator.

B, planetocentric latitude of the earth above the plane of the orbit.

The values of $u-U$, P′, a, b are to be interpolated directly for the times for which the apparent positions of the satellite are required, and the position-angles p and distances s of the satellite are then found by means of the formulæ

$$s \sin (P'-p) = a \sin (u-U)$$
$$s \cos (P'-p) = b \cos (u-U).$$

The satellite moves in the direction of decreasing position-angles, and will be at its greatest elongations (*nf* in pos. P′+90°, *sp* in pos. P′−90° at distance *a*), and at its conjunctions (*sup*erior in pos. P′, *inf*erior in pos. P′+180° at distance *b*) at the following Greenwich times:

1888.		h		1888.		h		1889.		h	
Oct.	29	9·1	inf.	Dec.	19	19·9	sp.	Feb.	7	19·1	nf.
	30	20·4	nf.		21	7·1	inf.		9	6·4	sup.
Nov.	1	7·7	sup.		22	18·4	nf.		10	17·6	sp.
	2	18·9	sp.		24	5·7	sup.		12	4·9	inf.
	4	6·2	inf.		25	17·0	sp.		13	16·2	nf.
	5	17·5	nf.		27	4·3	inf.		15	3·4	sup.
	7	4 8	sup.		28	15·5	nf.		16	14·7	sp.
	8	16 1	sp.		30	2·8	sup.		18	1·9	inf.
	10	3·4	inf.		31	14·1	sp.		19	13·2	nf.
	11	14·6	nf.	1889.					21	0·5	sup.
	13	1·9	sup.	Jan.	2	1·4	inf.		22	11·7	sp.
	14	13·2	sp.		3	12·6	nf.		23	23·0	inf.
	16	0·5	inf.		4	23·9	sup.		25	10·3	nf.
	17	11·7	nf.		6	11·2	sp.		26	21·5	sup.
	18	23·0	sup.		7	22·5	inf.		28	8·8	sp.
	20	10·3	sp.		9	9·7	nf.	Mar.	1	20·0	inf.
	21	21·6	inf.		10	21·0	sup.		3	7·3	nf.
	23	8·9	nf.		12	8·3	sp.		4	18·5	sup.
	24	20·1	sup.		13	19·5	inf.		6	5·8	sp.
	26	7·4	sp.		15	6·8	nf.		7	17·0	inf.
	27	18·7	inf.		16	18·1	sup.		9	4·3	nf.
	29	6·0	nf.		18	5·4	sp.		10	15·6	sup.
	30	17·3	sup.		19	16·6	inf.		12	2·8	sp.
Dec.	2	4·5	sp.		21	3·9	nf.		13	14·1	inf.
	3	15·8	inf.		22	15·2	sup.		15	1·3	nf.
	5	3·1	nf.		24	2·4	sp.		16	12·6	sup.
	6	14·4	sup.		25	13·7	inf.		17	23·8	sp.
	8	1·6	sp.		27	1·0	nf.		19	11·1	inf.
	9	12·9	inf.		28	12·2	sup.		20	22·3	nf.
	11	0·2	nf.		29	23·5	sp.		22	9·6	sup.
	12	11·5	sup.		31	10·8	inf.		23	20·8	sp.
	13	22·8	sp.	Feb.	1	22·0	nf		25	8·1	inf.
	15	10·0	inf.		3	9·3	sup.		26	19·3	nf.
	16	21·3	nf.		4	20·6	sp.		28	6·6	sup.
	18	8·6	sup.		6	7·8	inf.		29	17·8	sp.

INDEX.

PAGE

Adams, Prof. J. C., remarks on Sir George Airy's "Numerical Lunar Theory" 319
Adelaide Observatory, observations and elements of Comet *a* 1888 (Sawerthal) 397
Airy, Sir G. B., the numerical lunar theory 77, 253
———— note on his numerical lunar theory 204
———— numerical lunar theory, remarks on, Prof. Adams 319
Almucantar, note on the 224
Argentine General Catalogue for 1875, note on the probable errors of the star-places of, Mr. Downing 19
Associates deceased, list of 157
Astronomy, notes on the progress of, during the year 1887 :—
Discovery of minor planets 199
The comets of 1887 ..... *ib.*
The transit of *Venus*, 1882 201
The total solar eclipse of August 19, 1887 202
Sir George Airy's numerical lunar theory 204
Prof. Auwers's investigation of the Sun's diameter 206
The catalogue of the Paris Observatory 208
The Dunsink Catalogue of 1,012 southern stars 209
Heliometer determinations of the relative places of the principal stars of the *Pleiades* 210
The International Astrophotographic Congress, 1887 212
Spectroscopic astronomy in 1887 218
Photographic study of stellar spectra 220
Schiaparelli's observations of *Mars* in 1882 223
The Liverpool Astronomical Society 224
The Almucantar ..... *ib.*
Auditors, report of the 149
Auwers, Prof., note on his investigation of the Sun's diameter 206
———— presentation of medal to 236

Backhouse, T. W., nebula in *Andromeda* and *Nova*, 1885 108
———— the total eclipse of the Moon, 1888, Jan. 28 300
Becker, L., note on Comet *a* 1888 (Sawerthal) 380
Belding, Capt. R., sextant observations of Comet *a* 1888, extracted from the meteorological log kept on board the barque "Atlantic" ... 349
Biggs, A. B., observations of Comet *a* 1888 (Sawerthal), made at Launceston, Tasmania 348, 376
Bryant, R., the opposition of *Sappho* (80) in 1888 94
———— erratum 316

PAGE

Candidates proposed as Fellows of the Society 145, 253, 317, 351
Cape Catalogue for 1880, note on the probable errors of the star-places of, Mr. Downing 19
Central office for astronomical telegrams, Prof. Krueger 352
Christie, W. H. M., description of the personal equation machine of the Royal Observatory, Greenwich 1
Clarke, Capt. James, sextant observations of Comet *a* 1888 311
Comets:—
1886 VII. (Finlay), observed at Orwell Park Observatory, Mr. Plummer 55
1886 VIII. (Barnard), observed at Orwell Park Observatory, Mr. Plummer 56
1886 IX. (Barnard-Hartwig), observed at Orwell Park Observatory, Mr. Plummer 57
1887 II. (Brooks), observed at Orwell Park Observatory, Mr. Plummer 58
1887 III. (Barnard), observed at Orwell Park Observatory, Mr. Plummer 61
1887 IV. (Barnard, May 12), observed at Orwell Park Observatory, Mr. Plummer ..... *ib.*
1888 *a* (Sawerthal), discovery of, Dr. Gill 295
——— observed at the Royal Observatory, Greenwich 309, 341, 344, 373
——— observed at Grahamstown, Cape of Good Hope, Mr. Eddie 310
——— sextant observations of, Capt. J. Clarke 311
——— observed at Windsor, New South Wales, Mr. Tebbutt 312, 376
——— observed at the Radcliffe Observatory, Oxford 345, 375
——— observed at Launceston, Tasmania, Mr. Biggs 348, 376
——— sextant observations of, Capt. Belding 349
——— note on, Dr. Becker 380
——— sextant observations of, Capt. Dart 398
——— elements of, and observations, made at the Adelaide Observatory 397
Comets of 1887, note on the 199
Common, A. A., note on testing polished flat surfaces 105
Copeland, R., the total solar eclipse of 1887, August 19 48
——— note on the visible spectrum of the great nebula in *Orion* ... 360
Cross reticule, the, Lieut.-Col. Tupman 96
Crossley, E., an improved centering tube for reflecting telescopes 280
——— description of a new observatory for a 3-foot reflector 356

Dart, Capt. L. C., sextant observations of Comet *a* 1888 (Sawerthal) 398
Denning, W. F., the chief meteor showers 110
——— heights of fireballs and shooting stars 112
——— the total eclipse of the Moon, 1888, Jan. 28 301
Doberck, W., telegraphic determination of the longitude of Haiphong ... 282
Double-image micrometer: on the condition that the value of a revolution of the micrometer screw be independent of the accommodation of the eye, Prof. Oudemans 334
Downing, A. M. W., note on the probable errors of the star-places of the Argentine General Catalogue for 1875, and the Cape Catalogue for 1880 19
——— the positions for 1750·0 and proper motions of 154 stars south of −29° declination, deduced from a revision of Powalky's reduction of the star-places of Lacaille's Astronomiæ Fundamenta 322
Dreyer, J. L. E., occultations of stars during the total eclipse of the Moon, 1888, Jan. 28, observed at the Armagh Observatory ... 268

PAGE

Dunsink Catalogue of 1,012 southern stars, note on the 209
Dunsink Observatory, occultation of *Regulus* by the Moon 66

Eclipse of the Moon, 1888, Jan. 28, observed at Armagh, Dr. Dreyer ... 268
——— observed at Dunsink, Mr. Rambaut ..... *ib.*
——— at the Glasgow Observatory 272
——— at Liverpool, Mr. Hartnup ..... *ib.*
——— at the Radcliffe Observatory 273
——— at the Oxford University Observatory ... 275
——— at Stonyhurst, Rev. S. J. Perry 276
——— at Harrow, Lieut.-Col. Tupman 279
——— at the Royal Observatory, Cape of Good Hope 297
——— at Sunderland, Mr. Backhouse 300
——— at Bristol, Mr. Denning 301
——— at the Natal Observatory, Mr. Nevill 339
Eclipse, total solar, Committee 318
Eclipse, total solar, of 1887, August 19, Dr. Copeland 48
——— Rev. S. J. Perry 51
——— note on 202
Eclipse, total solar, of 1889, Jan. 1, note on, Mr. Hind 93
——— probable meteorological conditions at the time, Prof. Holden 302
Eclipse, total solar, of 1889, Dec. 21–22, note on, Mr. Hind 318
Eddie, L. A., the new southern comet [Sawerthal]; observations made at Grahamstown, Cape of Good Hope 310
Electrical control, on a simple method of applying, to the driving clock of an equatorial, Mr. Ranyard 336
——— new arrangement of, for driving clocks of equatorials, Sir H. Grubb 352
Elger, T. G., physical observations of *Saturn* in 1888 362
Ellery, R. L. J., Observations of *Sappho* made at the Melbourne Observatory 394

Fellows deceased, list of 157
——— elected 1, 77, 85, 145, 253, 297, 317
Franks, W. S., introduction to a catalogue of the mean colours of 758 stars; with an appendix, containing the colours of 26 southern stars 265

Gill, D., Comet Sawerthal, 1888 295
——— on the occultations of Döllen's list of stars, observed at the Royal Observatory, Cape of Good Hope, during the total eclipse of the Moon, 1888, Jan. 28 297
Glaisher, J. W. L., Address on presenting the gold medal to Dr. Arthur Auwers 236
Glasenapp, Prof. S., orbit of the binary star λ *Ophiuchi* 254
Glasgow Observatory, observations of stars made in connection with the total eclipse of the Moon, 1888, Jan. 28 272
Glasgow Star Catalogue, note on, Prof. Grant 381
Gore, J. G., on the orbit of *p Eridani* 26
——— on the double star Σ 1847 78
——— on the orbit of 70 (*p*) *Ophiuchi* 257
——— observations of the variable star S (10) *Sagittæ* 264
Graham, A., observations of *Sappho* made at the Cambridge Observatory with the Northumberland equatorial and square bar micrometer 337
Grant, Prof. R., note on the Glasgow Star Catalogue 381
Greenwich, Royal Observatory, description of the personal equation machine, Mr. Christie 1
——— results obtained with the personal equation machine, Mr. Turner 4

PAGE

Greenwich, spectroscopic results for the motions of stars in the line of sight, obtained in the year 1887, No. XI. 116
———— Royal Observatory, observations of occultations of stars by the Moon, and phenomena of *Jupiter's* satellites, made in the year 1887 123
———— observations of Comet *a* 1888 (Sawerthal) 309, 341, 373
———————— errata 382
———— observations of the spectrum of Comet *a* 1888 (Sawerthal)... 344
Grubb, Sir H., new arrangement of electrical control for driving clocks of equatorials..... 352

Hartnup, J., occultations of stars observed at the Liverpool Observatory, Bidston, Birkenhead, during the total eclipse of the Moon, 1888, Jan. 28 272
Hind, J. R., note on the total solar eclipse of 1889, Jan. 1..... 93
———— note on the total solar eclipse of 1889, Dec. 21–22..... 318
Holden, E. S., the total solar eclipse of 1889, Jan. 1, in California: probable meteorological conditions at that time 302
———————— the ring nebula in *Lyra*..... 383
———————— and J. M. Schæberle, observations of nebulæ at the Lick Observatory 388

International Astrophotographic Congress, 1887, note on the 212

Johnson, Rev. S. J., occultation of *Regulus* 67
———————— southern double stars 257
Jupiter, ephemeris for physical observations of, Mr. Marth 68
———— satellites of, on the appearances presented during transit, &c., Dr. Spitta 32
———————————— observed at the Royal Observatory, Greenwich ... 126
———————————— observed at Windsor, New South Wales, Mr. Tebbutt 129

Kövesligethy, R. de, on invisible stars of perceptible actinic power 114
Krueger, Prof. A., central office for astronomical telegrams 352

Lacaille's Astronomiæ Fundamenta (Powalky's revision of): positions and proper motions of 154 stars, Mr. Downing 322
Library, regulations for the 317
———— hours of closing..... 351
Light, amount of, reflected from the different portions of an unpolished sphere, Dr. Spitta... 32
Liverpool Astronomical Society, note on the..... 224
Longitude of Haiphong, telegraphic determination of, Dr. Doberck 282
———— of Mr. Tebbutt's Observatory, Windsor, New South Wales, Mr. Tebbutt 313
Lunar theory:—
The numerical lunar theory, Sir G. B. Airy 77, 253
Observations of the Moon, made at the Radcliffe Observatory, and comparison of the results with the tabular places from Hansen's Tables, Mr. Stone..... ... 86
Note on Sir G. Airy's numerical lunar theory 204
Remarks on Sir G. Airy's numerical lunar theory, Prof. Adams... 319

Marcsfield Observatory, note on the latitude and longitude of, Capt. Noble..... 67
Mars, ephemeris for physical observations of, Mr. Marth 78
———— ephemeris of the satellites of 136
———— note on Schiaparelli's observations of..... 223
———— note on, Mr. Proctor 307
Marth, A., ephemeris for physical observations of *Jupiter*, 1888 68
———————— ephemeris for physical observations of *Mars*, 1888 78

PAGE

Marth, A., ephemeris of the satellites of *Mars*, 1888 136
——— ephemeris of the satellites of *Uranus*, 1888 140
——— ephemeris for physical observations of the Moon for the nine lunations from April 12 to the end of 1888 285
——— ephemerides of the satellites of *Saturn*, 1888–89 398
——— ephemeris of the satellite of *Neptune*, 1888–89 410

Melbourne Observatory, observations of *Sappho* (80) made with the South Equatorial and dark-field filar micrometer, by P. Baracchi 394
Meteors: the chief meteor showers, Mr. Denning 110
——— heights of fireballs and shooting stars 112
Minor planets, note on the discovery of 199
Moon, ephemeris for physical observations of, Mr. Marth 285

Nebulæ:
Photographs of nebulæ and clusters, Mr. Roberts 29
Nebula in *Andromeda* and nova, 1885, Mr. Backhouse 108
Note on the visible spectrum of the Great Nebula in *Orion*, Dr. Copeland 360
The ring nebula in *Lyra*, Prof. Holden 383
Observations of nebulæ made at the Lick Observatory, Prof. Holden and Mr. Schæberle 388
Neptune, ephemeris of the satellite of, Mr. Marth 410
Nevill, E., occultations of stars observed during the lunar eclipse of 1888, Jan. 28 339
Noble, Capt. W., note on the latitude and longitude of Maresfield Observatory 67

Obituary: List of Fellows and Associates deceased 157
Baxendell, Joseph ..... *ib.*
Callcott, W. R. S. 160
Dancer, J. B. 161
Gaskin, Thomas ..... *ib.*
Gray, Peter 163
Ladd, Richard 165
Lettsom, W. G. ..... *ib.*
Morris, Alfred 166
Stewart, Balfour ..... *ib.*
Walden, J. M. 169
Waud, S. W. ..... *ib.*
Luther, Eduard ..... *ib.*
Schjellerup, H. C. F. C. 171
Observatories, accounts of proceedings of, during 1887:—
Greenwich, Royal 175
Edinburgh, Royal 179
Cape of Good Hope, Royal 180
Armagh 184
Cambridge 185
Dunsink 186
Glasgow 187
Kew ..... *ib.*
Liverpool 189
Oxford, Radcliffe 190
Oxford, University 191
Rugby 192
Stonyhurst ..... *ib.*
Mr. Common's, Ealing 193
Earl of Crawford's, Dun Echt 194
Mr. Crossley's, Bermerside, Halifax 195

PAGE

Observatories (*continued*):—
Mr. Huggins's, Upper Tulse Hill 195
Mr. Peek's, Lyme Regis 196
Col. Tomline's, Orwell Park 197
Lieut.-Colonel Tupman's, Harrow ..... *ib.*
Observatory for a 3-foot reflector, description of, Mr. Crossley 356
Oudemans, J. A. C., request to observers of variable stars 85
——— on the condition that in a double-image micrometer the value of a revolution of the micrometer screw be independent of the accommodation of the eye 334
Oxford, Radcliffe Observatory, observations of occultations of stars made during the total lunar eclipse of 1888, Jan. 28 273
——— observations of Comet *a* 1888 (Sawerthal) 345, 375
Oxford University Observatory, observations of stars occulted by the Moon during the eclipse of 1888, Jan. 28 275

Paris Observatory, note on the catalogue of the 208
Perry, Rev. S. J., the total solar eclipse of 1887, Aug. 19 51
——— notes on the solar surface of 1887 106
——— total eclipse of the Moon, 1888, Jan. 28 276
Personal equation machine of the Royal Observatory, Greenwich, description of, Mr. Christie 1
——— results obtained with, Mr. Turner 4
Peters, Prof. C. H. F., observations of *Sappho* (80) 370
Photographic Committee, resolutions of 351
——— images of bright stars, Gen. Tennant 104
Photographs, celestial, on the measurement of, Mr. Roberts 31
Pleiades, note on heliometer determinations of stars of the 210
Plummer, J. I., observations of comets made at the Orwell Park Observatory in the years 1886-87 55
Polished flat surfaces, note on testing, Mr. Common 105
Powalky's revision of Lacaille's Astronomiæ Fundamenta: positions and proper motions of 154 stars, Mr. Downing 322
Pritchard, Prof. C., further researches on stellar parallax by the photographic method 27
Proctor, R. A., note on *Mars* 307

Rambaut, A. A., the total lunar eclipse of 1888, Jan. 28, observed at the Dunsink Observatory 268
Ranyard, A. C., note on a simple method of applying electrical control to the driving clock of an equatorial 336
Reflecting telescopes, note on the definition of, Gen. Tennant 104
——— an improved centering tube for, Mr. Crossley 280
Report of the Council to the Sixty-Eighth Annual General Meeting of the Society 145
List of papers read from February 1887 to February 1888 226
List of donors to the Library, &c. 231
President's address on presenting the gold medal to Dr. A. Auwers 236
List of officers and council 252
Roberts, I., photographs of the nebulæ 57 M *Lyræ*: 27 M *Vulpeculæ*; the cluster 13 M *Herculis*; and of stars in *Cygnus* 29
——— on the measurement of celestial photographs (extract from a letter to the President) 31

Safford, T. H., on the reduction of star-places by Bohnenberger's method 20
Sappho (80), the opposition of, in 1888, Mr. Bryant 94
——— observations of, made at the Cambridge Observatory, Mr. Graham 337

PAGE

Sappho (80), observations of, Prof. Peters 370
——— observations of, made at the Melbourne Observatory 354
——— observations of, made at the Tacubaya Observatory, Mexico 393
Saturn, physical observations of, in 1888, Mr. Elger 362
——— ephemerides of the satellites of, 1888–89, Mr. Marth 398
——— occultation of, by the Moon, Mr. Tebbutt 396
Schiaparelli's observation of *Mars* in 1882, note on 223
Solar diameter, note on Prof. Auwers's investigation of 206
—— surface of 1887, notes on the, Rev. S. J. Perry 106
Spectroscopic astronomy in 1887, note on 218
Spitta, E. J., on the appearances presented by the satellites of *Jupiter* during transit, with a photometric estimation of their relative albedos, and of the amount of light reflected from the different portions of an unpolished sphere 32
Star colours: introduction to a catalogue of the mean colours of 758 stars; with an appendix containing the colours of 26 Southern stars, Mr. Franks 265
Star-places, on the reduction of, by Bohnenberger's method, Prof. Safford 20
Stars, bright, on their images on photographic plates, Gen. Tennant 104
Stars, invisible, of perceptible actinic power, Dr. de Kövesligethy 114
Stars, double:—
On the orbit of *p Eridani*, Mr. Gore 26
On the double star Σ 1847, Mr. Gore 78
Orbit of the binary star λ *Ophiuchi*, Prof. Glasenapp 254
Southern double stars, Rev. S. J. Johnson 257
On the orbit of 70 (*p*) *Ophiuchi*, Mr. Gore ..... *ib.*
Stars, motions of, in the line of sight, spectroscopic results obtained at the Royal Observatory, Greenwich, in the year 1887. No. XI. ... 116
Stars, variable, request to observers of, Prof. Oudemans 85
——— observations of the variable star S (10) *Sagittæ*, Mr. Gore 264
Stars, occultations of, by the Moon:—
Occultation of *Regulus*, observed at Dunsink Observatory 66
——— observed by Rev. S. J. Johnson 67
Observed at the Royal Observatory, Greenwich 123
Stars, occultations of, during the lunar eclipse of 1887, Jan. 28:—
Observed at Armagh, Dr. Dreyer 268
——— at Dunsink, Mr. Rambaut ..... *ib.*
——— at Glasgow Observatory 272
——— at the Liverpool Observatory ..... *ib.*
——— at the Radcliffe Observatory, Oxford 273
——— at the Oxford University Observatory 275
——— at Stonyhurst Observatory, Rev. S. J. Perry 276
——— at Harrow, Lieut.-Col. Tupman 279
——— at the Royal Observatory, Cape of Good Hope 297
——— at Sunderland, Mr. Backhouse 300
——— at Bristol, Mr. Denning 301
——— at the Natal Observatory, Mr. Nevill 339
Stellar parallax by the photographic method, further researches on, Prof. Pritchard 27
Stellar spectra, note on photographic study of 220
Stone, E. J., observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1887, and a comparison of the results with the tabular places from Hansen's Lunar Tables ... 86

Tacubaya Observatory, results of observations of *Sappho* (80) 393
Tebbutt, J., observations of phenomena of *Jupiter's* satellites at Windsor, New South Wales, in the year 1887 129

PAGE

Tebbett, J., observations of Comet *a* 1888 ..... 312, 376
——— on the difference of longitude between Mr. Tebbutt's Observatory, Windsor, New South Wales, and the Government Observatories at Sydney and Melbourne 313
——— observation of the occultation of *Venus* by the Moon, 1888, March 9 340
——— observation of the occultation of *Saturn* by the Moon, 1888, June 13 396
Tennant, Lieut.-Gen. J. F., note on the definition of reflecting telescopes and on the images of bright stars on photographic plates 104
Transit of *Venus*, 1882, note on the 201
Treasurer's account for 1887 146
Tupman, G. L., on the cross reticule 96
——— occultations observed at Harrow during the total eclipse of the Moon, 1888, Jan. 28 279
Turner, H. H., results obtained with the personal equation machine at the Royal Observatory, Greenwich 4

Uranus, ephemeris of the satellites of, Mr. Marth 140

Venus, occultation of, by the Moon, 1888, March 9, Mr. Tebbutt 340
——— note on the transit of, 1882 201

LIST OF PRESENTS

RECEIVED DURING THE SESSION OF 1887–88,

AND OF

BOOKS PURCHASED WITH THE TURNOR AND HORROX FUNDS

DURING THE SAME PERIOD,

FORMING

APPENDIX IV.

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